A COMPARATIVE EVALUATION OF THE MARGINAL ADAPTATION AND FRACTURE RESISTANCE OF THREE DIFFERENT TYPES OF METAL FREE CERAMIC SYSTEMS WITH METAL CROWN-AN INVITRO STUDY

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In the partial fulfillment of the degree of

MASTER OF DENTAL SURGERY

Branch I

Prosthodontics and Crown & Bridge

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CERTIFICATE

This is to certify that this dissertation titled "**A comparative evaluation of the marginal adaptation and fracture resistance of three different types of metal free ceramic systems with metal crown - an in vitro study**" is a bonafide record of work done by **Priya .M.S.** under our guidance during her postgraduate study during the period ***2009-2012*** under **THE TAMIL NADU DR MGR MEDICAL UNIVERSITY, CHENNAI** in partial fulfillment for the degree of **MASTER OF DENTAL SURGERY IN PROSTHODONTICS & CROWN BRIDGE, BRANCH I.** It has not been submitted (partial or full) for the award of any other degree or diploma.

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I hereby declare that this dissertation entitled "**A comparative evaluation of the marginal adaptation and fracture resistance of three different types of metal free ceramic systems with metal crown - an in vitro study**" is a bonafide record of work undertaken by me and that this thesis or a part of it has not been presented earlier for the award of any degree, diploma, fellowship or similar title of recognition.

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Gurur Devo Maheshwara

Guru Sakshath Parambrahmai

Tasmay shree Gurave namaha"

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Abstract

Aims & objectives

The purpose of the present study is:

1. To compare the marginal adaptation of copings and crowns of three different metal free ceramic systems against a standard metal crown.
2. To compare the marginal adaptation between the copings of three different types of metal free ceramic systems.
3. To compare the marginal adaptation between the crowns of three different types of metal free ceramic systems.
4. To compare the marginal adaptation between the copings and crowns of three different types of metal free ceramic systems.
5. To compare the fracture resistance of three different types of metal free ceramic systems against a standard metal crown.
6. To compare the fracture resistance between the copings of three different types of metal free ceramic systems.
7. To compare the fracture resistance between the crowns of three different types of metal free ceramic systems.
8. To compare the fracture resistance between the copings and crowns of three different types of metal free ceramic systems.

Materials & Methods

Six copings and six crowns each of three commercial metal free ceramic systems, a) IPS e.max (Ivoclar Vivadent AG, Schan /Liechtenstein), b) Procera All ceram (Nobel biocare, Sweden), and c) Cercon (Dentsply, Degudent,) were fabricated in a standardized manner. Thus a total of 18 copings and 18 crowns were fabricated and compared against a Cobalt-chromium metal coping and crown (Wirobond C) for marginal adaptation and fracture resistance. Individual heat cure acrylic resin dies (Viade Products Inc. Camarillo, California) were fabricated for each coping and crown (a total of 48) to check for marginal adaptation and fracture resistance. After copings were made, they were placed on individual dies to check for marginal adaptation using a stereomicroscope. Later crowns were fabricated and marginal adaptation checked . The copings and crowns were luted on to their definitive dies using dual cure resin luting agent (Rely X, 3M ESPE, St Paul, Minn) and fracture resistance assessed with a Universal testing machine (Instron).

Results:

Analysis of variance ANOVA was the statistical tool employed to analyze the data.

1. The metal restoration showed better marginal adaptation for copings and crowns.
2. Procera All Ceram exhibited maximum marginal gap when the marginal adaptation of copings were compared.
3. Cercon crown presented with maximum marginal gap.
4. Marginal adaptation of crowns of all ceramic systems was less than that of their respective copings. Metal crown and coping exhibited similar marginal adaptation.
5. Fracture resistance of IPS e.max crowns was considerably low when compared to the metal and other three systems.

6. Fracture resistance of crowns was higher than the coping, except for IPS e.max, which had similar value.

Conclusion

In the present study it was concluded that there were variations among the all ceramic systems with regard to marginal adaptation and fracture resistance. IPS e.max system had the least amount of marginal gap for copings and crowns between the three all-ceramic systems compared. Layering ceramic application increases the marginal gap of all-ceramic systems. But since all these values are within the clinically acceptable limits, all three can be successfully used for crown fabrication. Fracture resistance of Procera All ceram and Cercon coping were comparable to metal coping. IPS e.max coping had fracture resistance significantly lower than other all ceramic system. There was no significant difference in strength of IPS e.max copings and crowns. Cercon crown had the highest fracture resistance value. Since the fracture resistance of all these copings and crowns were well above the maximum masticatory load, they can be successfully used for posterior areas of mouth.

Introduction

Ceramic materials are one of the oldest restorative materials used in dentistry. They are exquisite esthetic dental restorative materials owing to their extreme chemical stability and precise shade simulation with human teeth. They are also one of the most biocompatible materials in restorative dentistry. Ceramics are unique for their appearance, can be customized to simulate color translucency and fluorescence of human teeth.

The major limitation with use of ceramics as tooth replacement material is their very fragile fracture toughness and hence fracture occurs at a very low strain rate of 0.1%. The flexural strength of ceramics is relatively poor as compared to other esthetic resilient dental restorative materials.

The earliest successful porcelain systems used conventional feldspathic porcelain, derived from the natural mineral feldspar. This material was used for producing all ceramic jacket crowns, which were very esthetic, but extremely susceptible to fracture. To overcome this problem, Porcelain fused to metal systems were introduced by the incorporation of Leucite crystals into the feldspathic porcelain composition which were used to veneer the cast gold alloy substructure. The leucite crystals served to increase the thermal expansion of the porcelain to bring it closer to that of metal substructure, thus increasing bonding and strength.

Although the porcelain fused to metal system possess high strength, the resultant opacity of the metal substructure which compromised esthetics has encouraged the development of all ceramic core materials containing crystalline components which are stronger than the traditional predominantly glassy, amorphous feldspathic porcelain. This type of core material can then be veneered with a more translucent ceramic material and an esthetically pleasing restoration could be accomplished.

Various all-ceramic systems have been discussed in the literature regarding their processing techniques, strength and wear characteristics. Although in-vitro studies have shown significant differences in the strength and hardness of some of these materials, the results of long term clinical studies are very less.

Newer ceramic materials and innovative ceramic processing techniques have been introduced in restorative dentistry since the early 1980s. Some of these ceramics still share roots with research that originated in Europe in the 18th century. Today most advances are derived from collaborations with the ceramics engineering community.

Notable recent progress includes the advent of newer ceramic materials and techniques for esthetic complete crowns, partial coverage and laminate veneer restorations, improved metal ceramic esthetics with the advent of opalascent porcelains and frame work modifications, introduction of CAD/CAM and machining as a route to fabrication of restorations, improved understanding of the clinical response of all ceramic prostheses and of the material factors that influence clinical longevity.

The uses of all ceramic materials for fixed restorations have become a key topic in esthetically oriented dentistry. Recent progress in material technology and manufacturing procedures has extended the implications not only for inlays, but also for single crown restorations. In addition to fracture resistance and esthetics, marginal fit is one of the most important criteria for the long term success of all ceramic crowns. Marginal discrepancies expose luting material to the oral environment thus leading to cement dissolution, caused by oral environment.

Ceramic materials can be classified based on material composition as silica based and non silica based. Silica based ceramic materials can be again divided into conventional feldspathic porcelain and reinforced pressed ceramics. The non silica based materials can be again classified into sintered, infiltrated (both are created according to slip cast technique), densely sintered, high putty aluminum, and zirconium oxide ceramic (fabricated through CAD/CAM technique .Due to their mechanical and aesthetic qualities and bio compatibility CAD/CAM generated restorations have gained acceptance in dentistry. They are called digital ceramic restorations. Among these materials Procera system has long term performance, mechanical properties and aesthetic capabilities. The versatility of Procera allows it to be used for veneers, crowns, abutments and fixed partial dentures.

By using CAD/CAM to fabricate only the sub structure of a given restoration, we are able to combine innovative technology and conventional steps, mixing the reliability and reproducibility of industrial digital manufacturing with the artistic skills of dental technicians responsible for the ceramic stratification. These CAD/CAM techniques are now applied to highly pure and densely sintered aluminum oxide, zirconium oxide and titanium materials (Esthetic integration of digital–ceramic restorations by Touati, Etienne, Vandooren).

Stereo microscope was used for evaluating the marginal discrepancies in copings and crowns of three different types of metal free ceramic systems used for the study. The studies conducted by Matty F. et al, (1989) and In –Sung Yeo et al, (2003) showed that IPS e.max has better marginal adaptability than the other types of all ceramic crowns. Ando et al, in their study concluded that marginal discrepancy increased after firing as a result of heat treatment for degassing. McLean et al, (1971) in their clinical study of 1000 restorations over a five year period, concluded that 120µm was the clinically acceptable marginal discrepancy (maximum).

Hence this study was done to evaluate the marginal adaptation copings and crowns of three different types of metal free ceramic systems, and their fracture resistance.

Aims & Objectives

1. To compare the marginal adaptation of copings and crowns of three different types of metal free ceramic systems against a standard metal crown.
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Review of Literature

Gordon J. Christensen, (1971) has discussed some of the recent advances in cast-gold dental treatment at that time. A study of the microscopic adaptation of the margins of crowns finished on various die materials showed superior results with silver-plated dies. He has suggested that margins be (1) burnished in the mouth with a blunt burnisher; (2) disked with extra-fine cuttle, coarse, medium, and fine 3/8 inch disks, respectively; and (3) cemented. The use of silver-plated dies eliminates the need for the use of all but the finest cuttle disks in the mouth, because the technician had previously finished the margins on the silver die. Castings finished on silver-plated dies will have closer marginal adaptation regardless of whether the margins are above or below the gingiva, since intraoral finishing of gingival margins is nearly impossible.[1]

Valderhaug (1977) studied oral hygiene, the gingival condition, pocket depth, and the incidence of caries on crowned teeth during a period of 5 years in a group of patients (114) who had been treated with fixed dental prostheses. Prior to the prosthetic treatment, the patients received periodontal treatment. During the study, the subjects participated in an oral hygiene program. Crown margins were located sub-gingivally, at the gingiva and supra-gingivally. When the crown margins were located sub-gingivally, there was an increase in Gingival Index scores 2, and in pocket depth, compared to supra-gingival placement. An improvement of gingival health was recorded where the crown margins were located supra-gingivally. Caries lesions developed on 3.5% of the tooth surfaces which had received crowns.[2]

McLean J (1979) through his book titled the Science and Art of Dental Ceramics has provided the dental profession with methods and materials for restoring teeth not only to function but to things of beauty. The mechanical properties of porcelain have been discussed and has reached the opinion that they are brittle materials with very low plastic deformation. However their strength values are much higher making them suitable for clinical usage in a variety of situations.[3]

Lang et al 1983 evaluated the changes occurring in the sub gingival microbiota in children following the placement of orthodontic bands in the absence of a prophylactic oral hygiene program. Following tooth-banding, a statistically significant increase from baseline values ($p<0.05$) was found for the percentages of black-pigmented bacteroides, the B. intermedius and A. odontolyticus species, concomitantly with a decrease of the anaerobe/facultative bacteria ratio in the experimental, but not the control sites. These results document the potential of subgingivally placed orthodontic bands in changing the sub gingival ecosystem in subjects without special oral hygiene instructions favoring the dominance of periodontopathic micro-organisms.[4]

Kwanchai A. Gomez, Arturo A. Gomez (1984), Statistical analysis – of variance was done to assess the influence of various fixed partial dentures crown materials on marginal adaptation and fracture of copings and crowns.[5]

Belser et al (1985) carried out a scanning electron microscopy to estimate the fit of three porcelain fused to metal marginal designs in vivo. Marginal gaps were measured with an SEM on replicas derived from elastomeric impressions. There was no significant difference among beveled metal margins, metal butt margins, or porcelain butt margins either before or after cementation at the 95% confidence level. This study has shown that it is possible under clinical conditions to consistently produce porcelain butt margins with less than 50 μ marginal opening in PFM restorations.[6]

Holmes (1989) has described in his work that the measurements of misfit at different locations are geometrically related to each other and defined as internal gap, marginal gap, vertical marginal discrepancy, and horizontal marginal discrepancy, overextended margin, under extended margin, absolute marginal discrepancy, and seating discrepancy. The significance and difference in magnitude of different locations are presented. The best alternative is perhaps the absolute marginal discrepancy, which would always be the largest measurement of error at the margin and would reflect the total misfit at that point.[7]

Hopkins (1989) estimated the effect of specimen thickness on the strength of dental porcelain. It has been shown that for core, dentine and combinations of these porcelains, the shell strength decreases with increasing thickness. Consequently, the load carrying capacity does not increase as much as might be expected with thicker sections. Possible reasons for this phenomenon and methods of limiting this effect are discussed.[8]

Jacobs MS, Windeler AS (1991) investigated the rate of type I zinc phosphate cement solubility as it relates to the degree of marginal opening. Standardized test samples were constructed that would simulate clinically relevant marginal gaps of 25, 50, 75, and 150 microns and their subsequent cement lines. The study was divided into two phases, that is, cement solubility in a static environment and a dynamic environment. Both the phase 1 and phase 2 studies demonstrated no significant difference in the rate of cement dissolution for the 25-, 50-, and 75-micron test groups. The 150-micron test groups for both studies, however, demonstrated an increase in the rate of cement dissolution.[9]

Weaver et al (1991) evaluated the marginal adaptation of castable ceramic crowns, Dicor, Cerestore, and porcelain-fused-to-metal crowns. The shoulder preparation was maintained for ceramic crowns, and a cavosurface bevel was designed for metal ceramic crowns. Crowns were made with a replication size of 10, placed on master dies, and the marginal openings measured with a Nikon Measurescope 20 instrument. Thirty crowns were cemented with zinc phosphate cement at the recommended clinical force. Marginal adaptation was not improved with a gingival bevel preparation or an increased seating force. The best marginal adaptation was recorded for Cerestore crowns.[10]

Anusavice K J and Hojjatie B (1992) analyzed the relative effect of loading site, occlusal thickness, ceramic flaws, elastic modulus of the cement, and voids in the cement layer on tensile stress that develops in molar glass-ceramic crowns under applied loads. Finite-element stress analyses were performed. For a ceramic thickness of 0.5 mm and a vertical distributed load applied at a distance of 1.3 mm from the vertical axis, the maximum tensile stresses were 100 MPa for a crown with flaws and a void, 87 MPa for a crown with no flaws and a void, and 75 MPa for a crown with flaws and no void. For a 1.5-mm-thick crown with flaws and a void, the tensile stress decreased to 22 MPa. When the load of 600 N was concentrated at the central point of the occlusal region, the peak tensile stress in a crown with flaws and no void was increased to 325 MPa. For the conditions analyzed in this study a large void in a flawed occlusal region of a thin molar crown (0.5 mm) is proposed as a mechanism of crown failure.[11]

Scherrer (1993) evaluated the fracture resistance of all-ceramic crowns as a function of the elastic modulus of the supporting die. All-ceramic crowns were made for dies with three different elastic moduli and two different crown lengths. The occlusal surface was loaded in compression with a 12.7-mm steel ball. The fracture load increased markedly with the increase in elastic modulus. The largest increase was seen when only the occlusal surface of the crown was covered. The characteristic fracture load of the complete-crown restorations was more than double that of the occlusal-cover restorations in the dies with the lowest modulus of elasticity, while for the dies with the highest modulus of elasticity the difference in the characteristic fracture load for the two configurations was not significant.[12]

Castellani et al (1994) evaluated the fracture resistance of three types of all-ceramic crowns and compared these to the fracture values of metal ceramics. Uniform metal ceramic specimens; veneered, cast glass-ceramic; and porcelain fused to two different dispersion-strengthened ceramic cores (Hi-Ceram and In-Ceram) were investigated. The metal ceramic specimens demonstrated a significantly higher resistance to fracture than did the Hi-Ceram or veneered glass-ceramic units but did not significantly differ from the In-Ceram specimens. The metal ceramic crowns showed cracks only in the ceramic layer, whereas the all-ceramic specimens underwent global fracture.[13]

Sano et al (1994) studied the tensile properties of mineralised and demineralised human and bovine dentin. Small slabs (4 x 0.5 x 0.5 mm) of bovine and human dentin were tested in a microtensile testing device in vitro. Human coronal mineralized dentin gave a mean ultimate tensile strength (UTS) of 104 MPa. Bovine incisor coronal dentin exhibited UTS of 91 MPa, and bovine root dentin failed at 129 MPa. The modulus of elasticity of mineralized bovine and human dentin varied from 13 to 15 MPa. When dentin specimens were demineralized in EDTA, the UTS and modulus of elasticity fell to 26-32 MPa and 0.25 GPa, respectively, depending on dentin specimens. The results indicate that collagen contributes about 30% of the UTS of mineralized dentin, which is higher than was expected.[14]

Yoshinari and Derand (1994) compared the fracture strengths of four types of all-ceramic premolar crowns (conventional Vitadur, In-Ceram, Dicor, and IPS-Empress) after a preload cycling in aqueous atmosphere. Preload cycling significantly decreased the strength of Vitadur crowns. Fracture strength of Vitadur crowns were improved when they were luted with either polyalkenoate or adhesive resin cement.

The In-Ceram crowns fractured in two modes: complete fractures at 1276 (207) N; and fractures with the core remaining intact at 808 (292) N.[15]

Burke FJ (1995) investigated the effect of dentinal bonding and ceramic etching procedures on the fracture resistance of all-ceramic crowns. These results were compared with the fracture resistance of similar crowns placed with a nonadhesive conventional cement. All results indicated that superior fracture resistance was obtained when dentinal bonding was incorporated into the luting procedure together with etching of the ceramic fitting surface and the use of resin-based luting material. The fracture resistance of specimens luted with such a procedure was significantly greater than that of specimens in which conventional non-adhesive cement was used.[16]

Seghi RR and Sorenson JA (1995) studied the flexural strength of six recently introduced dental ceramic materials using a three-point-bend test. Conventional feldspathic porcelain and soda-lime glass were used as controls. All six of the new materials had significantly greater flexural strength than the controls. The alumina-based crystalline-reinforced materials exhibited the highest breaking strengths. The silica-based crystalline-reinforced materials resulted in ceramic materials with more moderate strength but still with significantly greater strength than the controls. Scanning electron microscopic analysis of the fractured surfaces indicated crack deflection appeared to be the principle strengthening mechanism in the highly crystalline materials.[17]

Tuntiprawon M, Wilson PR. (1995) evaluated the effect of cement thickness on the fracture strength of all ceramic crowns. Thirty-three aluminous porcelain jacket crowns were divided into three groups. In Group 1, only platinum foil was used to provide cement space. In Group 2 two layers and Group 3 four layers of die spacer were painted onto the metal die before impression making. Each crown was cemented onto a metal die with zinc phosphate cement and loaded until fracture. It was concluded that increasing the cement thickness above 70 microns reduced the fracture strength of porcelain jacket crowns.[18]

Wagner and Chu (1996) compared the biaxial flexural strength and indentation fracture toughness of three new dental core ceramics, Empress, In-Ceram, and Procera AllCeram ceramics. They were prepared according to their manufacturers' recommendations. The results revealed significant differences in flexural strength for the three materials ($p \leq 0.05$). The average flexural strengths of AllCeram, In Ceram, and Empress Ceramics were 687 MPa, 352 MPa, and 134 MPa respectively. There was no statistically significant difference between the fracture toughness of Procera ($4.48 \quad \mathrm{MPa} \cdot \mathrm{m}^{1/2}$) and In-Ceram ceramics ($4.49 \quad \mathrm{MPa} \cdot \mathrm{m}^{1/2}$); however, both ceramics had significantly higher fracture toughness ($p < 0.005$) than Empress ceramic ($1.74 \quad \mathrm{MPa} \cdot \mathrm{m}^{1/2}$).[19]

Sulaiman et al (1997) carried out an in vitro study to compare the marginal fit of three all-ceramic crown systems (In-Ceram, Procera, and IPS Empress). All crown systems were significantly different from each other at P = 0.05. In-Ceram exhibited the greatest marginal discrepancy (161 microns), followed by Procera (83 microns), and IPS Empress (63 microns). There were no significant differences among the various stages of the crown fabrication: core fabrication, porcelain veneering, and glazing. The facial and lingual margins exhibited significantly larger marginal discrepancies than the mesial and distal margins.[20]

Andersson et al (1998) summarized from the data from the many studies on Procera All Ceram crowns that have been conducted at clinical and laboratory centres around the world. The evidence reported in these studies clearly demonstrated that the Procera AllCeram crown represents a combination of computer technology and creativity for which a positive prognosis can be made. Today its application is restricted to single crowns; however, with continued development, multiple unit all-ceramic anterior and posterior fixed partial dentures will be avilable.[21]

May et al (1998) measured the precision of fit of the Procera AllCeram crown fabricated with Procera CAD/CAM technology for the premolar and molar teeth fitted to a die. Laser videography was used to measure the gap dimension between the crowns and the dies at the marginal opening, the axial wall, the cusp tip, and the occlusal adaptation measurement locations. Mean gap dimensions and standard deviations (SDs) were calculated for marginal opening, internal adaptation, and precision of fit.[22]

Zeng et al (1998) describes the mechanical testing of dental ceramic core materials in combination with porcelains to simulate the real service conditions for dental applications. The study included Procera AllCeram, Vita In-Ceram, three dental porcelains (Procera Porcelain AllCeram, Vitadur-N, and Vitadur Alpha); and densely sintered alumina-Procera Porcelain AllCeram two-layer composites, densely sintered alumina-Vitadur-N two-layer composites, and glass-infiltrated presintered alumina-Vitadur Alpha two-layer composites, with different thicknesses of densely sintered alumina or glass-infiltrated presintered alumina, respectively. The flexural tests were performed in ring-on-ring biaxial bending. Results indicated that the failure stress of densely sintered alumina is significantly higher than that of glass-infiltrated presintered alumina as a core dental material under the same testing conditions. The failure stresses of the three commercial dental porcelains are statistically the same. It was concluded that the densely sintered alumina-Procera Porcelain AllCeram two-layer composite has interesting dental applications.[23]

Strub JR, Beschnidt M. (1998) evaluated the fracture resistance of 5 different all-ceramic crown systems (In-Ceram, Empress staining technique, Empress veneering technique, Celay feldspathic system, and Celay In-Ceram system) before and after cyclic preloading in an simulated mouth. It was found that the chewing simulation and the thermocycling significantly decreased the fracture strength of all tested crown systems ($P < 0.01$). There were no statistically significant differences between the all-ceramic crown groups and the PFM crowns.[24]

Sobrinho et al (1998) investigated the influence of fatigue on the fracture strength of In-Ceram (Vita Zahnfabrik), Optimal Pressable Ceramic (OPC, Jeneric Pentron), and IPS Empress (Ivoclar-Vivadent) in both wet and dry environments. The results indicated that the fracture strength for In-Ceram was significantly stronger than IPS Empress. No difference was found between In-Ceram and OPC, and OPC and IPS

Empress. The fatigue values of the three ceramic systems decreased significantly in both dry and wet environments. This may be due to crack propagation from pre existing flaws. No difference was found between fatiguing in dry and wet environments[25].

Brunton, Mc Cord and Wilson (1999) is discussing about a new ceramic material, Procera AllCeram, with universal anterior and posterior applications. It was recently introduced to the UK by Nobel Biocare (Sweden). This type of restoration has a densely sintered, high purity, alumina core and was first described in 1993. These restorations are produced in a unique manner using technology initially developed to produce titanium copings for implant abutments by spark erosion. This article also offers suggestions for case selection, preparation design, and luting procedures.[26]

Kelly JR (1999) in the article, clinically relevant approach to failure testing of all-ceramic restorations, has reviewed characteristics of the traditional load-to-failure test, contrasted these with characteristics of clinical failure for all-ceramic restorations, and sought to explain the discrepancies. Variables considered to be important in simulating clinical conditions were described along with their recent laboratory evaluation. It was concluded that traditional fracture tests of single unit all-ceramic prostheses are inappropriate, because they do not create failure mechanisms seen in retrieved clinical specimens. Validated tests are needed to elucidate the role(s) that cementing systems, bonding, occlusion, and even metal copings play in the success of fixed prostheses and to make meaningful comparisons possible among novel ceramic and metal substructures.[27]

Beschnidt and Strub (1999) evaluated the marginal fit of different all-ceramic crown systems after simulation in the simulated mouth. The in vitro marginal fit of five different all-ceramic crown systems (In-Ceram®, Empress® staining technique, Empress® veneering technique, Celay® feldspathic system, Celay In-Ceram® system) was evaluated before and after cyclic preloading in an artificial mouth and were compared to those for porcelain-fused-to-metal (PFM) crowns with circular porcelain-butt margins which were cemented with zinc phosphate cement. It was observed that crown cementation increased the marginal gaps significantly ($P<0{\cdot}01$). Empress® staining technique crowns showed the smallest marginal gaps (median 47 µm), followed by conventional In-Ceram® crowns (median 60 µm) and Empress® veneer technique crowns (median 62 µm). Celay In-Ceram® crowns displayed marginal openings with a median of 78 µm, followed by Celay® feldspathic crowns with a median of 99 µm. Ageing in the chewing simulator had no significant influence on the marginal fit of all specimens. The study indicated that all the tested all-ceramic crowns have clinically acceptable margins.[28]

Holand et al (2000) analyzed the microstructures of glass-ceramics of the IPS Empress 2 and IPS Empress systems by scanning electron microscopy. The main properties of the glass-ceramics were determined and compared to each other. The flexural strength of the pressed glass-ceramic (core material) was improved by a factor of more than three for IPS Empress 2 (lithium disilicate glass-ceramic) in comparison with IPS Empress (leucite glass-ceramic). Abrasion behavior, chemical durability, and optical properties such as translucency of all glass-ceramics fulfill the dental standards. The authors concluded that IPS Empress 2 can be used to fabricate 3-unit bridges up to the second premolar.[29]

Drummond et al (2000) has evaluated the flexure strength under static and cyclic loading and the fracture toughness under static loading of six restorative ceramic materials. It was proved that the lithium disilicate containing ceramic had significantly higher flexure strength and fracture toughness when compared to the four pressable leucite strengthened ceramics and the low fusing conventional porcelain. All of the leucite containing pressable ceramics did provide an increase in mean flexural strength (17–19%) and mean fracture toughness (3–64%) over the conventional feldspathic porcelain. Further, the influence of testing environment and loading conditions implies that these ceramic materials in the oral cavity might be susceptible to cyclic fatigue, resulting in a significant decrease in the survival time of all-ceramic restorations.[30]

Stokes et al (2001) evaluated the dynamic fracture energies and patterns of fracture in extracted human central incisors of intact controls, groups with Vitadur N® crowns, Vita Hi Ceram® crowns, Dicor® crowns and porcelain veneers. Teeth were struck on their middle labial surfaces by a pendulum impact device. The mean fracture energy for teeth with Dicor crowns was significantly lower than for all other groups. Control tooth crowns fractured obliquely in an apical direction. Vitadur N® and Dicor® crowns, shattered, the underlying tooth usually fracturing in the plane of the impact force. Vita Hi Ceram® crowns chipped at the site of impact and some fractures were located in the roots. Gold crowns remained cemented and fracture occurred at the crown/root junction, or in the root. Porcelain veneers fractured at the site of impact but remained cemented. Dicor® crowns were less fracture resistant than other restoration types tested. Porcelain veneers and full gold crowns stiffened teeth which led to more root fractures than the porcelain crowns.[31]

Guazzato et al (2002) compared the mechanical properties of In-Ceram Zirconia and In-Ceram Alumina. Mean biaxial flexure strengths of In-Ceram Alumina and In-Ceram Zirconia were 600 MPa (SD 60) and 620 MPa (SD 61), respectively. Mean fracture toughness measured according to indentation strength was 3.2 MPa $\cdot m^{1/2}$ for In-Ceram Alumina and 4.0 MPa $\cdot m^{1/2}$ for In-Ceram Zirconia. Mean fracture toughnesses of In-Ceram Alumina and In-Ceram Zirconia measured according to indentation fracture were 2.7 MPa $m \cdot^{1/2}$ and 3.0 MPa $m^{1/2}$ respectively. X-ray diffraction analysis showed that little phase transformation from tetragonal to monoclinic occurred when the specimens were fractured, supporting the existence of a modest difference of fracture toughness between the two ceramics. It was concluded that no statistically significant difference was found in strength. In-Ceram Zirconia was tougher ($P < .01$) than In-Ceram Alumina when tested according to indentation strength. However, no significant difference was found in the fracture toughness when tested with the indentation fracture technique.[32]

Blatz et al 2003 in the article resin ceramic bonding presents a literature review on the resin bond to dental ceramics. Although the resin bond to silica-based ceramics is well researched and documented, few in vitro studies on the resin bond to high-strength ceramic materials were identified. Available data suggest that resin bonding to these materials is less predictable and requires substantially different bonding methods than to silica-based ceramics. The few available studies on resin bonding to zirconium oxide ceramics suggest the use of resin cements that contain special adhesive monomers.[33]

Webber et al (2003) investigated the effect of different thickness of veneer porcelain on the compressive load at fracture of Procera AllCeram crowns. Sixty brass dies were fabricated with a crown-like preparation and a chamfer margin. Sixty crowns were fabricated with a 0.6-mm-thick core: Procera crowns with either a 0.4-mm- or 0.9-mm-thick veneer of AllCeram (Groups 1 and 2 respectively) or In-Ceram crowns with a 0.9-mm-thick veneer of Vitadur Alpha porcelain (Group 3). Each group consisted of 20 crowns. In-Ceram crowns were used as the control group. Panavia 21 TC Dental Adhesive served as the luting agent. After luting, fracture resistance was tested using Universal testing machine. It was proved that the axial thickness of veneer porcelain did not have a significant effect on the compressive load at fracture of Procera AllCeram crowns.[34]

Harrington et al (2003) investigated the load at fracture of Procera AllCeram Crowns with various thickness of occlusal veneer porcelain, Fifty resin dies were manufactured to incorporate the features of an all-ceramic crown preparation on a premolar tooth. Fifty corresponding crowns were constructed and divided into five groups. Groups 1, 2, 3, and 4 were crowns with 0.6-mm-thick Procera cores and 0.4-mm-thick axial veneer porcelain and the remaining sample was not veneered , 0.4 mm, 0.9 mm, and 1.4 mm, respectively. Group 5 specimens consisted of 0.6-mm-thick In-Ceram cores with 0.4 mm of axial porcelain and 0.4 mm of occlusal porcelain. The crowns were cemented onto their respective dies with a resin luting agent. And tested in a universal testing machine. The mean loads at fracture were 419 N (group 1), 702 N (group 2), 1,142 N (group 3), 1,297 N (group 4), and 732 N (group 5) It was concluded that increasing the thickness of the occlusal veneer porcelain increased the load at fracture for Procera AllCeram crowns. There was no significant difference in load at fracture between the Procera and In-Ceram crowns.[35]

Olsson et al (2003) evaluated the long-term outcome of In-Ceram Alumina fixed partial dentures (FPD) performed in a general dental practice from 1992 to1996. The study was conducted as a retrospective assessment of up to 9 years of patient records and a clinical follow-up examination of patients treated with In-Ceram Alumina FPDs. In 37 patients, 42 FPDs had been inserted during the selected period. The mean time in function for the 42 FPDs was 76 months, with 86% being followed for > 5 years. No adverse effects to either periodontal or pulpal tissues were recorded. The technical quality was very good, and patient satisfaction very high. Five FPDs fractured during the observation period, resulting in a total failure rate of 12%. Cumulative survival rate according to life table analysis was 93% after 5 years and 83% after 10 years. The results suggest that the In-Ceram Alumina short-span FPD is a viable prosthetic alternative.[36]

Anusavice (2003) has explained in detail about the mechanical properties of dental materials in the textbook Phillip's Art and Science of dental materials. The various factors affecting the ultimate strength as well as fracture toughness assessment of brittle materials has been explained. The importance of surface flaws on stress concentration is also dealt with in this chapter.[37]

Sundh and Sjogren (2004) evaluated the fracture strengths of stabilized all-ceramic crowns manufactured using an yttrium-oxide-partially-stabilized (Y-TZP) zirconia ceramic core (Denzir) veneered with lithium disilicate glass-ceramics (IPS Empress 2 or IPS Eris) were evaluated. The Denzir cores were manufactured in two ways: either with different thickness in different parts of the restoration, called an 'adapted Denzir core'; or with a uniform core thickness of 0.5 mm. IPS Empress 2 all-ceramic crowns served as reference. There was no significant difference between the crowns with an 'adapted Denzir core' veneered with the two brands of glass-ceramics. No significant difference was seen between the crowns with a 0.5 mm Denzir core veneered with the two brands of glass-ceramics. The crowns with an 'adapted Denzir core' exhibited significantly higher values than those with a 0.5 mm Denzir core and than the IPS Empress 2 crowns used as reference.[38]

Kelly J R (2004) in the article Dental ceramics, Current thinking and trends has presented all-ceramics within a simple framework allowing for easy understanding of their composition and development. He has also provided for a classification of ceramics based on composition and structure. The meaning of strength and details of the fracture process are explored, and recommendations are given regarding making structural comparisons among ceramics. Assessment of clinical survival data is dealt with, and literature is reviewed on the clinical behavior of metal-ceramic and all-ceramic systems. Practical aspects are presented regarding the choice and use of dental ceramics.[39]

Narong Potiket, (2004) evaluated the in vitro fracture strength of teeth restored with crowns made of 3 different types of 2 all-ceramic crown systems—0.4-mm and 0.6-mm aluminum oxide coping crowns and zirconia ceramic coping crowns—and metal-ceramic crowns. All restorations were treated with bonding agent (Clearfil SE Bond) and luted with phosphate-monomer–modified adhesive cement (Panavia 21). Fracture strength was tested with a universal testing machine at a crosshead speed of 2 mm per minute with an angle of 30 degrees to the long axis of the tooth. It was found that there was no significant difference between groups. There was no significant difference in the fracture strength of teeth restored with all-ceramic and metal-ceramic restorations in this in vitro study. The all-ceramic crown may be considered to be an alternative restoration for highly esthetic areas.[40]

Quintas et al (2004) conducted an vitro study to evaluate the effect of different finish lines, ceramic manufacturing techniques, and luting agents on the vertical discrepancy of ceramic copings. The two finish lines considered were heavy chamfer and rounded shoulder. Luting agents tested included zinc phosphate, resin-modified glass ionomer (Fuji Plus), and resin composite cements (Panavia F). Procera copings presented the lowest mean values of vertical marginal discrepancy before and after cementation (25/44 mm) when compared to Empress 2 (68/110 mm) and InCeram Alumina copings (57/117 mm), regardless of any combinations among all finish lines and luting agents tested. This study confirmed that the ceramic manufacturing technique influenced marginal discrepancy of all-ceramic copings.[41]

Komine et al (2004) evaluated the fracture resistance of aluminum oxide ceramic, cemented with different resin luting agents before and after cyclic loading. The results of this in vitro study showed that the selection of the adhesive resin cement may influence the fracture strength of aluminum oxide ceramic posterior crowns. All cements tested were capable of successfully luting aluminum oxide ceramic crowns. The fracture strength of crowns luted with Panavia F after artificial aging was significantly lower than Panavia F specimens that were not artificially aged. The results of this in vitro study showed that the selection of the adhesive resin cement may influence the fracture strength of aluminum oxide ceramic posterior crowns.[42]

Pallis et al (2004) made an experimental observation of the failure loads of all-ceramic crowns using a steel ball intender. The 95% confidence intervals for characteristic failure loads were 771 to 1115N for IPS Empress 2, 859 to 1086 for Procera All ceram and 998 to 1183 for In ceram Zirconia. There was no significant difference in fracture resistance, although there was a significant difference in failure origin. The origin of failure was most commonly found at the interface between the ceramic core and veneer porcelain for IPS Empress II and between the ceramic core and luting agent layer for the other systems. Two–way multivariant analysis of variance was used to analyze the thickness of the luting agent, ceramic core, and veneer porcelain layers.[43]

Reich S (2005) evaluated the clinical fit of all-ceramic three-unit fixed partial dentures (FPD), generated with three different CAD/CAM systems. Twenty-four all-ceramic FPDs were fabricated and randomly subdivided into three equally sized groups. Eight frameworks were fabricated using the Digident CAD/CAM system (DIGI), another eight frameworks using the Cerec Inlab system (INLA). Vita Inceram Zirkonia blanks were used for both groups. In a third group frameworks were milled from yttrium-stabilized Zirconium blanks using the Lava system (LAVA). All frameworks were layered with ceramic veneering material. In addition, six three-unit metal-ceramic FPDs served as control group. All FPDs were evaluated using a replica technique with a light body silicone stabilized with a heavy body material. The replica samples were examined under microscope. The means of marginal gaps were 75 micron for DIGI, 65 micron for LAVA and INLA and 54 micron for the conventional FPDs. Only the DIGI data differed significantly from those of the conventional FPDs. Within the limits of this study, the results suggested that the accuracy of CAD/CAM generated three-unit FPDs is satisfactory for clinical use.[44]

Bindal and Mormann (2005) made an experimental observation of the marginal and internal fit of all ceramic CAD/CAM crown copings on chamfer preparation. Slip cast,(Inceram Zirconia) ,heat pressing (Empress II) and CAD/CAM (Cerec in Lab, DCS, Decim and Procera) crown copings were seated on 12 dies each . Marginal and internal gap width was measured in the SEM at 120X magnification. It was found that the marginal gap of Empress II was significantly larger than In-ceram zirconia. Procera and Decim had values similar to In-ceram. The internal mid orobuccal gap width was highest for Procera and lowest for Decim. In-ceram, Empress II, DCS and Cerec InLab had values in between. But the fit of conventional and CAD/CAM all-ceramic molar crown copings covered the range of assumed gap width.[45]

Luthy et al (2005) determined the strength and reliability of four-unit posterior frameworks made of glass ceramic with lithium-disilicate crystals (E2), of zirconia-reinforced glass-infiltrated alumina (ICZ) and of zirconia stabilized with 3 mol% yttria (CEZ). It was found that CEZ frameworks showed the best mechanical properties as demonstrated by the high values of average load bearing capacity, measured on a special bridge test, reliability and characteristic load bearing capacity with respect to the other ceramics studied. However, for four-unit posterior CEZ frameworks the connector size of 7.3 mm^2 is insufficient to withstand occlusal forces reported in the literature. Four-unit posterior frameworks require a connector size larger than7.3 sq.mm.[46]

Stappert (2005) evaluated the influence of preparation design on longevity and failure load of ceramic veneers bonded to human maxillary central incisors. The control group remained unprepared (NP). For Group WP, a window preparation was made. Specimens in Group IOP were prepared with an incisal overlap of 2 mm without palatal chamfer. For Group CVP, specimens were prepared with a complete-veneer design of 3-mm incisal reduction and 2-mm palatal extension. All the specimens were subjected to cyclic loading and thermal cycling in a dual-axis masticatory simulator. Within the limits of this in vitro investigation, the use of adhesively luted IPS Empress 1 veneers prepared according to the three different preparation designs demonstrated adequate stabilization of residual tooth structure. Crack pattern analysis showed a higher risk of subcritical crack development when the indenter impact was applied on the palatal ceramic surface. They have concluded that the palatal contact point position of the antagonist should remain on the natural tooth structure after preparation. In particular, this is important for complete veneer preparation.[47]

Sundh et al (2005) evaluated the effect of heat treatment and veneering on the fracture resistance of frameworks manufactured using sintered and subsequently hot isostatic pressed yttrium oxide partially stabilized zirconia (Denzir) after fatigue testing. It was found that cyclic loading in water did not significantly affect the fracture resistance. Heat treatment and veneering reduced the fracture resistance of hot isostatically pressed zirconia.[48]

Sadighpour et al (2006) reviewed the various mechanical test methods usually use to evaluate dental ceramic materials. The various test methods for determining the flexural strength, fracture toughness and fracture resistance has been reviewed in detail. They have also discussed the clinical implication of these tests and their limitations.[49]

Steyern et al (2006) investigated the fracture resistance of zirconia crowns and compared the results with crowns made of a material with known clinical performance (alumina). Sixty crowns were made, 30 identical crowns of alumina and 30 of zirconia and divided into three groups and subjected to (i) water storage only, (ii) pre-loading (10 000 cycles, 30–300 N, 1 Hz), (iii) thermocycling (5–55, 5000 cycles) + pre-loading (10 000 cycles, 30–300 N, 1 Hz). Subsequently, all 60 crowns were subjected to load until fracture occurred. It can be concluded that there is no difference in fracture strength between crowns made with zirconia cores compared with those made of alumina if they are subjected to load without any cyclic pre-load or thermocycling. There is, however, a significant difference in the fracture mode, suggesting that the zirconia core is stronger than the alumina core. Crowns made with zirconia cores have significantly higher fracture strengths after pre-loading.[50]

Studart et al (2007) in the article the in vitro lifetime of dental ceramics under cyclic loading in water has investigated the cyclic fatigue in water of three dental materials currently used as frameworks in all-ceramic restorations: a 3 mol%-yttria partially stabilized zirconia (3Y-TZP, Cercon, Degudent GmbH), an aluminum oxide-zirconium oxide–Glass composite (Inceram-Zirconia, Vita Zahnfabrik GmbH) and a lithium disilicate ($Li_2O{\cdot}2SiO_2$) glass ceramic (Empress 2, Ivoclar Vivadent AG). In spite of its noticeable susceptibility to fatigue in water, the 3Y-TZP material was found to be particularly suitable for the preparation of posterior all-ceramic bridges due to its high initial mechanical strength. Guidelines are provided for the selection of materials and the design of all-ceramic posterior bridges exhibiting lifetime longer than 20 years under severe wet and cyclic loading conditions.[51]

Aboushelib (2007) evaluated both the fracture and impact strength of two core veneered all-ceramic systems to reveal whether the speed of loading affects fracture mechanism. The absorbed energy by IPS Empress-Eris crowns and Cercon-Ceram S crowns in a fracture strength test was compared by the energy absorbed in an impact strength test. The principles of fractography were used to identify fracture origin and dimensions and to calculate the stress at failure. Finite element analysis (FEA) was used to rationalize the results. For the IPS Empress 2-Eris crowns, there was a significant difference in the energy absorbed for the fracture test and the impact test, where for the Cercon-Ceram S, there was no significant difference. Despite the high strength of the zirconia cores there was no significant difference in the energy absorbed between the two systems in the impact strength test. The dominant mode of failure of layered all-ceramic restorations under occlusal loading is cone cracking in the veneering ceramic.[52]

Di Lorio et al (2008) compared the resistance to fracture under a cyclic load applied to chamfer-edged vs. shoulder-edged Procera All Ceram cores. An extracted first maxillary premolar was prepared with a 50 degrees chamfer margin using conventional diamond burs, and an impression was made using a polyvinylsiloxane to fabricate brass dies. The alumina cores were then cemented on the brass dies and underwent a fracture test with a cyclic load for 24 hours. Fragments were retrieved for fracture characterization using scanning electron microscopy (SEM). The mean values of fracture resistance for the chamfer samples were 406.10, 67.271 N and 643.90 32.912 N for the shoulder samples. The results of this in vitro study indicate a relationship between the cervical thickness of the alumina cores and their fracture resistance. A shoulder margin could improve the biomechanical performance of posterior single crown alumina restorations.[53]

Shirakura et al. (2009) assessed the influence of veneering porcelain thickness of all ceramic and metal ceramic crowns on failure resistance after cyclic loading. Two different frame work designs with 2 different incisal thickness of veneering porcelain were used (2mm,&4mm) for all ceramic (Procera all ceram) and metal ceramic crown system. The all ceramic group showed significantly higher success and survival rates than the metal ceramic group. For the failure load ,the 2-way ANOVA showed significant effects for material and porcelain thickness. Procera All Ceram crowns may allow up to approximately 4mm of feldspathic porcelain on the incisal area without increasing the failure rate or decreasing the failure load.[54]

Tao J, Han D (2009) investigated the effect of finish line curvature on marginal fit of all-ceramic CAD/CAM crowns and metal-ceramic crowns. Three types of finish line curvature abutments (1-, 3-, and 5-mm curvature) were prepared on typodont maxillary central incisors. For each type of abutment, 5 all-ceramic crowns (Cercon system, DeguDent) and 5 metal-ceramic crowns were fabricated. The marginal gaps of copings and veneered crowns were measured on a profile projector. It was found that the abutment finish line curvature had no significant effect on the marginal fit of all-ceramic crowns, but had a significant effect on the marginal fit of metal-ceramic crowns.[55]

Att et al. (2009) assessed the marginal adaptation of three different zirconium dioxide three unit fixed dental prosthesis at different fabrication stages and after artificial aging. The purpose of this study was to evaluate the marginal adaptation of different zirconia 3-unit fixed dental prostheses at different fabrication stages and after artificial aging. Twenty-four zirconia 3-unit fixed dental prostheses (DCS, Procera, and VITA YZ-Cerec; n=8) were fabricated using different manufacturing systems and conventionally cemented with glass ionomer cement on human teeth. Each group was aged in a masticatory simulator with thermal cycling. The marginal gaps were examined on epoxy replicas for frameworks and for restorations before and after cementation, and after masticatory simulation, at 250x magnification. Group VITA YZ-Cerec showed significantly smaller marginal gap values than groups DCS and Procera at framework ($P<.05$) and before-cementation ($P<.05$) stages. The VITA YZ-Cerec group showed significantly smaller marginal gap values than the Procera group after cementation ($P<.05$). The marginal gap values between different stages were not significantly different for all groups ($P>.05$). They have come to a conclusion that the marginal accuracy of zirconia fixed dental prosthesis is influenced by manufacturing technique.[56]

Comlekoglu et al (2009) evaluated the effect of different cervical finish line designs on the marginal adaptation of a zirconia ceramic. Four different marginal finish lines (c: chamfer, mc: mini-chamfer, fe: feather-edge and s: rounded shoulder) were prepared on phantom incisors and duplicated in epoxy resin. Y-TZP (ICE Zirkon) frameworks were manufactured by a copy-milling system (Zirconzahn) using prefabricated blanks and tried on the master models for initial adaptation of the framework; they were then sintered, followed by veneering (Zirconzahn). The finished crowns were cemented with a polycarboxylate cement (Poly F) under 300 g load and ultrasonically cleaned. The specimens were sliced and the marginal gap was measured, considering absolute marginal opening (AMO) and marginal opening (MO) for each coping under a stereomicroscope with image processing software (Lucia). It was found that the cervical finish line type had an influence on the marginal adaptation of the tested zirconia ceramic. For better marginal adaptation, both shoulder and mini-chamfer finish line types could be suggested for zirconia crowns.[57]

ElGuindy (2010) investigated the effect of different adhesive systems on the vertical marginal gap distance and the fracture resistance of lithium disilicate based crowns. Forty premolars were prepared to receive forty e-max crowns. The crowns were divided into 4 groups, Group (U): using RelyX Unicem resin cement (self-adhesive system). Group (V): Variolink II (total-etch system). Group (GU) and group (GV): application of G-bond (self-etch) on dentin preceded previously used adhesive systems. A stereomicroscope was used to record the vertical marginal gap distance before and after cementation. The crowns were subjected to cyclic loading and fracture resistance test. A scanning electron microscope was used to qualitatively examine the dentin/resin interface. It was concluded that ceramic restorations luted with total-etch system offer better vertical marginal adaptation and fracture resistance than restorations luted with self-adhesive system. Treatment of the dentin surface prior to the application of the bonding system is efficient.[58]

Hyun-Soon (2010) evaluated the influence of porcelain veneering on the marginal fit of Digident and Lava CAD/CAM zirconia ceramic crowns before and after porcelain veneering. 20 crowns were made per each system and the marginal fit was evaluated through a light microscope with image processing (Accura 2000) at 50 points that were randomly selected. Each crown was measured twice: the first measurement was done after obtaining the means and standard deviations of the marginal fit were 61.52 ± 2.88 μm for the Digident CAD/CAM zirconia ceramic crowns before porcelain veneering and 83.15 ± 3.51 μm after porcelain veneering. Lava CAD/CAM zirconia ceramic crowns showed means and standard deviations of 62.22 ± 1.78 μm before porcelain veneering and 82.03 ± 1.85 μm after porcelain veneering. Both groups showed significant differences when analyzing the marginal gaps before and after porcelain veneering within each group. However, no significant differences were found when comparing the marginal gaps of each group before porcelain veneering and after porcelain veneering as well. It can be concluded that the 2 all-ceramic crown systems showed marginal gaps that were within a reported clinically acceptable range of marginal discrepancy.[59]

Abhishek Rastogi and Vikas Kamble (2011) studied the effect of design on marginal adaptation of cast restorations, and compared the sensitivity and specificity of various clinical evaluation techniques. Twenty four castings were prepared with eight castings for each marginal design , i.e., buccal shoulder and beveled finish line, chamfer finish line. And a three-quarter crown preparation with proximal boxes and beveled finish line Each casting underwent examination with an explorer, disclosing media, and a stereomicroscope. Stereomicroscopy at a value less than or equal to 30 microns was used as a gold standard to evaluate the significance of different designs on marginal adaptation. Preparation designs examined in this study did not significantly affect the marginal adaptation of the castings. It was concluded that commonly used clinical evaluation techniques using explorer and disclosing media appeared to be inadequate for assessment of marginal accuracy.[60]

Materials & Methods

In the present study the following materials and methods were employed.

MATERIALS

1. Wax block for carving the die in the intended dimension (**The Hindustan dental Products** ,Chapel Road, Hydrabad)
2. Inlay wax (**Bego Co**, Bremen, Germany)
3. Phosphate bonded investment material (**Bellavest T**, Bego Co, Bremen, Germany)
4. Nickel-chromium alloy for the fabrication of the definitive die (**Wiron 99**, Bego Co, Bremen, Germany).
5. Polyvinyl siloxane Impression material (**Virtual VPS**, Ivoclar Vivadent, Amherst, NY)
6. Die stone Type IV (**Gyprock,** Rajkot**,** Gujarat, India)
7. Clear, heat cure acrylic for duplicating the metal die (**Viade Products Inc**. Camarillo, California)
8. Die spacer (**Siena,** Cergo, Dentsply)
9. Cobalt-Chromium (**Wirobond C**, Bego Co, Bremen, Germany)
10. **IPS e.max ingot** and veneering porcelain (**Ivoclar** Vivadent Amherst NY)
11. **Procera Allceram ingot** and veneering porcelain (**Nobel Biocare**, Sweden)
12. **Cercon ingot** and veneering porcelain (**Dentsply**, Degudent, Germany)
13. Investment material for fabrication of acrylic die (**Cergo fit**, Dentsply, DeguDent, Germany)
14. Investment material for IPS e.max (**IPS Press vest**, Ivoclar Vivadent , Amherst, NY)
15. Dual cure Resin luting agent (**Rely X**, 3M ESPE, St Paul, Minn)

EQUIPMENTS

1. Stereomicroscope (**Leica MZ 6**, Germany)
2. Press Furnace for IPS e.max (**EP600 Press**, Ivoclar Vivadent, Amherst,NY)
3. Pressure casting machine (**Shofu**, Shofu Inc, Japan)
4. Microblaster (**Penblaste**r,Shofu Inc, Japan
5. Ceramic furnace (**Progrmat P500**, Ivoclar Vivadent, Amherst, NY)
6. Universal testing machine (**Model 3345**; Instron Corp, Canton, Mass)

METHODOLOGY

A total of forty eight samples were fabricated for the study of which thirty six of them were made of metal free ceramic while twelve of them were metal samples.

From a wax block a tooth was carved identical to an all ceramic crown preparation on a maxillary first molar with a 1mm modified shoulder and 1.5 to 2mm occlusal reduction (1.5-mm reduction at the center of the occlusal table and 2.0-mm reduction at the cusps). This was invested in phosphate bonded investment material (Bella vest, Bego Co, Bremen,Germany), burned out and cast with Nickel chromium alloy (Wiron 99, Bego Co, Bremen,Germany) to fabricate a metal die with a crown height of 6mm and root length of 27 mm. Impression of the definitive metal die was made with polyvinyl siloxane (Vitual VPS, Ivoclar Vivadent Amherst NY). It was poured with inlay wax (Bego Co, Bremen,Germany), invested in investment material (Cergofit, Dentsply, Degudent, Germany). Forty eight duplicate dies were fabricated in a high filler content resin material (Viade Products Inc) to replicate the definitive die. The resin die material was selected because it has a modulus of elasticity (12.9 GPa) similar to that of human dentin (14.7 GPa).

Thirty six all-ceramic cores and crowns were fabricated from these three systems, IPS e.max, Procera AllCeram and Cercon. IPS E-max II is a recently introduced hot pressed ceramic.The major crystalline phase of the core material is a lithium disilicate. The material is pressed at 920º C (1690 ºF) For the fabrication of the core, a wax pattern is fabricated, it is invested using phosphate investment material .Then it is heated to 800 º C to burn out the wax pattern. A ceramic ingot of appropriate shade is placed in the special pressing furnace. After heating to 1150ºC, the softened ceramic is slowly pressed. Then it is allowed bench cool for 10 hours. The restoration is recovered from the investment by airborne particle abrasion with 55 µm glass beads, the sprue is removed and it is refitted to the die. Where as for Procera All Ceram and Cercon systems the fabrication procedure involves an industrial CAD/CAM process. The die is mechanically scanned by the technician. This data is send to the lab where an enlarged die is milled using a computer controlled milling machine. This enlargement is necessary to compensate for sintering shrinkage. Aluminum oxide powder is then compacted on to the die. The coping is milled before sintering at very high temperature. (1150 º C).The coping is further veneered with an aluminous ceramic with matched thermal expansion.

The crowns and cores were cemented onto resin dies (Viade Products Inc, Camarillo, Calif) for comparison of fracture resistance. Six IPS e.max (Ivoclar Vivadent) cores and crowns were fabricated to a thickness of 0.7 mm on the axial wall and 1.0 mm on the occlusal table using vacuum forming sheets (Henry Schein

Inc, Melville, NY) The Procera AllCeram cores were presintered, milled, and sintered by the manufacturer (Nobel Biocare USA, Yorba Linda, Calif). Six Cercon cores were fabricated by Vident using a CAD-CAM system. All Ceramic cores were fabricated to a thickness of 0.5mm on all surfaces. The twenty four crowns were completed with the application of the appropriate dentin and veneer porcelains. Vitadur Alpha porcelain (Vident, Brea Calif) was used to complete Procera AllCeram and Cercon crowns, while Eris porcelain (Ivoclar Vivadent) was used to complete the IPS e. max crowns. After the desired thickness of porcelain was achieved and evaluated using micrometer, eighteen ceramic cores were further fired according to the manufacturers' instructions. The restorations were ultrasonically cleaned in distilled water for 10 minutes.

The samples were grouped in to group I, group II. group III and group IV. IPS e.max, Procera All Ceram, Cercon and metal respectively. They were again subdivided in to A and B for convenience. Where A denotes coping and B crown.

MARGINAL ADAPTATION

Stereomicroscope, Leica (Germany) was used to evaluate the marginal discrepancy of copings and crowns. The images were captured by a digital camera and were analyzed with the help of Q. win software. To measure the precision of fit of a crown / core to the die, it is positioned on the die. For each specimen eight locations were used to determine the precision of fit between the crowns/cores to the dies (three on the buccal, three on the lingual and one each on the proximal). Mean data were calculated and analyzed statistically with descriptive statistics and repeated measurement analysis to assess the marginal adaptation between crown groups, coping groups , crowns and copings, and all ceramic systems with metal samples. The average gap dimension at each measurement location within each crown group was determined by calculating the means and standard deviations (SD).

FRACTURE TESTING

Six crowns and copings of each ceramic system were used for fracture testing. Due to variations in the alumina content of the ceramic compositions tested, different surface treatments were used. The internal surfaces of the IPS e.max copings and crowns were acid-etched with 9.5% hydrofluoric acid for 2.5 minutes in preparation for luting. (Ceramic Refill,IPS Ceramic Etching gel) The Procera AllCeram and Cercon crowns were prepared for luting by airborne-particle abrasion of the internal surfaces with 50 µm aluminum oxide at 80 psi (Ad Abrader; J. MoritaUSA Inc, Irvine, Calif) for 3 seconds. The surfaces of all forty eight dies were airborne-particle abraded with 50 mm aluminum oxide at 40 psi (Ad Abrader; J. Morita USA Inc) for 5 seconds. The surfaces of all forty eight crowns and copings were cleaned in distilled water for 10 minutes and air dried. All ceramic crowns were silanated (Monobond –S- Ivoclar Vivadent) and luted to the dies with a resin luting agent (Rely X; 3M ESPE AG, Dental products ,Seefeld, Germany). The crowns and copings were luted with finger pressure for 1 minute, light cured for 20 seconds. The excess luting agent was removed. Finger pressure was applied for another 5 minutes and each surface was light cured for 20 seconds.

A stainless steel ball bearing of 5.25 mm diameter was centered on the occlusal surface of each specimen. Each specimen was occlusally loaded along the long axis to fracture in a universal testing machine (Mode3345; Instron Corp, Canton, Mass) at a crosshead speed of 1mm/min, and the maximum load was recorded from the load-displacement trace.

DATA ANALYSIS:-

Analysis of variance was done to assess the influence of various fixed partial denture crown materials on marginal adaptation and fracture resistance and of copings and crowns [5].

Source	**Degrees of freedom**
Between groups (A)	3
Between copings and crowns (B)	1
Interaction (A x B)	3
Experimental error (E)	40
Total	47

Critical Difference (CD) = $t_{error\ DF} 0.5 \times \sqrt{2}$ MSE/r, where MSE is the experimental error variance as measured by mean square error from ANOVA. If the difference between a pair of means exceeds the CD, then the treatment with respect to the means are said to be significantly different.

Results

Table – 1: Analysis of variance for fracture resistance of copings and crowns of 4 groups

Source	**Degrees of freedom**	**Mean Square (MS)**	$\mathbf{F_{n1,n2}}$	**Table $\mathbf{F_{n1.n2}}$ 5%**	**1%**
Between groups (A)	3	3.0699	41.37**** *	2.84	4.31
Between copings and crowns (B)	1	13.1461	177.17**** *	4.08	7.31
Interaction (AxB)	3	22.3557	301.29**** *	2.84	4.31
Experimental error (E)	40	0.0742			
Total	47				

** significant at 1% level of significance

Table – 2 Mean fracture resistance (KN) of copings and crowns

Groups	Coping	Crown
Group 1- IPS e.max	1.20	1.02
Group 2- Procera All ceram	0.88	2.30
Group 3- Cercon	1.26	2.34
Group 4- Metal	1.40	3.26

$SE_{m\,=}$ 0.157

* CD for comparison of crown materials x copings/crowns = 0.318

Table – 3: Analysis of variance for marginal discrepancy of copings and crowns of 4 groups

Source	Degrees of freedom	Mean Square (MS)	$F_{n1,n2}$	Table $F_{n1.n2}$ 5%	1%
Between groups (A)	3	9745.6143	9227.05**** *	2.84	4.31
Between copings and crowns (B)	1	1121.6233	1061.94**** *	4.08	7.31
Interaction (AxB)	3	387.3329	366.72**** *	2.84	4.31
Experimental error (E)	40	1.0562			
Total	47				

** significant at 1% level of significance

Table – 4 Mean marginal discrepancy (µm) of copings and crowns

Groups	Coping	Crown
Group 1- IPS e.max	57.54	60.23
Group 2- Procera All ceram	88.48	99.17
Group 3- Cercon	83.35	108.65
Group 4- Metal	37.17	37.17

$SE_{m} = 0.593$

* CD for comparison of crown materials x copings/crowns = 1.199

Table (1) shows Analysis of Variance ANOVA to compare fracture resistance of copings and crowns of four groups of crown materials. ANOVA revealed that significant differences existed between the four groups compared.

Table (2) depicts the mean values of fracture resistance of copings and crowns of four groups tested.

It was found that no significant difference in fracture resistance was observed between copings and crowns in Group 1, ie, IPS e,max. While in all other groups, i.e., Procera All Ceram, Cercon and metal (Wirobond C) fracture resistance of crowns were high in comparison with copings.

Fracture resistance of Procera All ceram coping (Group 2) was significantly low in comparison to copings of IPS e.max, Cercon and metal Wirobond C. There was no significant difference in fracture resistance of copings between group 1, group 3 and group 4. In other words the fracture resistance of IPS e.max and Cercon did not differ significantly from the control metal group.

When the fracture resistance values of crowns between the four groups were compared it was observed that IPS e.max crown had a significantly low fracture resistance. There was no significant difference in fracture resistance between Procera All Ceram and Cercon. However a marked increase in strength was observed for crowns fabricated with metal Wirobond C. Fracture resistance of the control metal group was significantly higher than the 3 three all-ceramic systems studied.

Table (3) shows Analysis of Variance ANOVA to compare marginal discrepancy of copings and crowns of four groups of crown materials. ANOVA revealed that significant differences existed between the four groups compared.

Table (4) depicts the mean values of marginal discrepancy of copings and crowns of four groups tested.

It was found that there was a significant increase in marginal discrepancy of crowns of all three all-ceramic systems when compared to the copings. With metal Wirobond C the marginal discrepancy remained the same for both copings and crowns.

When the marginal discrepancy of copings was compared it was observed that there was a significant difference between all the four groups. Maximum discrepancy was registered for Procera All ceram followed by Cercon and IPS e. Max. Marginal discrepancies of three all-ceramic systems were significantly higher than the control metal group.

When the marginal discrepancies of crowns were compared there was a significant difference between the four groups, with maximum discrepancy exhibited by Cercon, followed by Procera All Ceram and IPS e.max. Again similar significant increase in marginal discrepancy was noted for all-ceramic systems when compared to crown of metal Wirobond C.

INFERENCES:-

1. There was no significant difference in fracture resistance values between copings and crowns of IPS e.max.
2. Fracture resistance values of crowns of Procera All Ceram, Cercon and metal Wirobond C were significantly higher than their corresponding coping.
3. Fracture resistance values of Procera Allceram coping was significantly low in comparison to copings of IPSe.max, Cercon and metal Wirobond C.
4. Fracture resistance values of IPS e.max, Cercon and metal Wirobond C coping were statistically similar.
5. Fracture resistance value of IPS e.max crown was significantly low in comparison to all other groups.
6. There was a statistically significant increase in marginal discrepancy of three all-ceramic system crowns when compared to their corresponding copings.
7. There was no difference in marginal gap between metal coping and crown.
8. Maximum marginal gap was exhibited by Procera All ceram coping when compared to copings of other three groups.
9. When marginal gaps of crowns were compared it was found that Cercon crown presented with maximum marginal gap.

Figures

Fig 1:-Wax block carved for fabrication of metal die.

Fig 2 :- Induction Casting machine for fabrication of Nickel Chromium definitive die

Fig 3 :- Definitive die fabricated in Nickel Chromium alloy Wiron 99

Fig 4:- Wax pattern for fabrication of IPS e.max core

Fig 5 :- Completed IPS e.max core after heat pressing using lost wax technique

Fig 6 :- Completed IPS e. Max crown after veneering

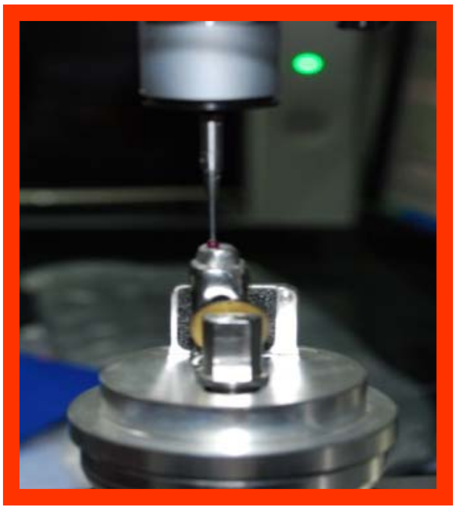


Fig 7:- Scanning of metal die for CAD/CAM coping of Cercon

Fig 8:- Digital impression for CAD/CAM manufacturing

Fig 9 : - Cercon ingot for computer aided machining

Fig 10:- Cercon coping and crown

Fig 11 :- Procera coping and crown

Fig 12 :- Test samples of each system before luting

Fig 13:- Luting procedure

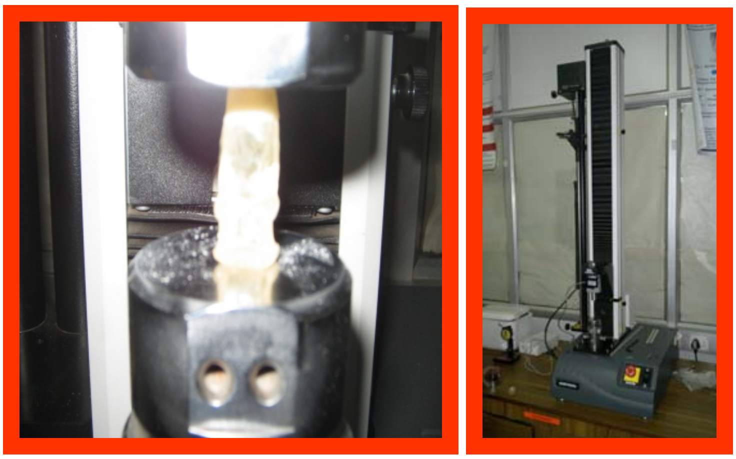


Fig 14 :- Instron Universal testing machine for assessing fracture resistance

Fig 15 :-Fractured Cercon crown

Fig 16 :- Fractured Procera crowns

Fig 17 :-Fractured IPS e.max crowns

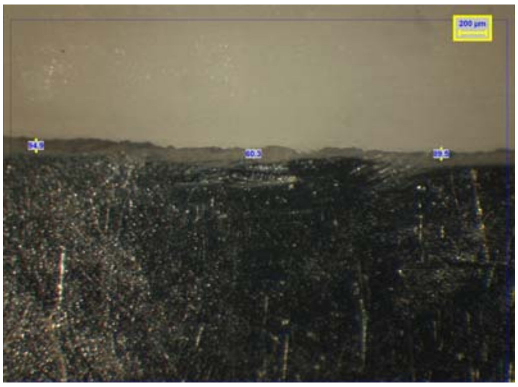


Fig 18:- Stereomicroscopic image depicting marginal gap in IPS e.max copings

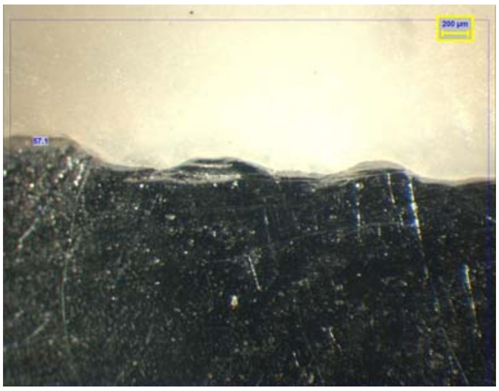


Fig 19 :- Stereomicroscopic image depicting marginal gap in Procera Allceram coping.

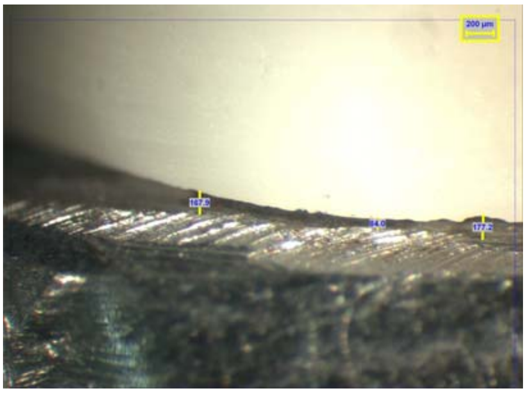


Fig 20:- Stereomicroscopic image depicting marginal gap in Cercon

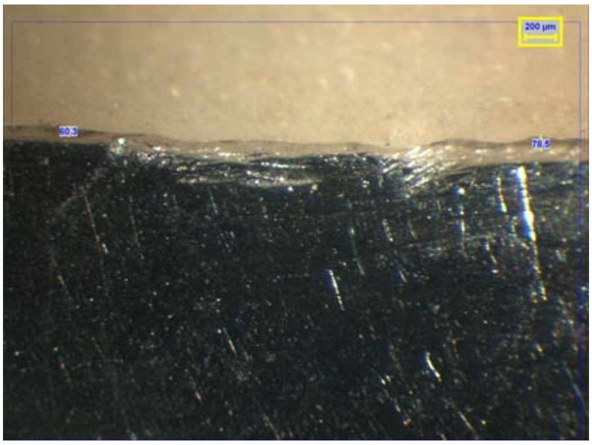


Fig 21 :- Stereomicroscopic image depicting marginal gap in IPS e.max crown

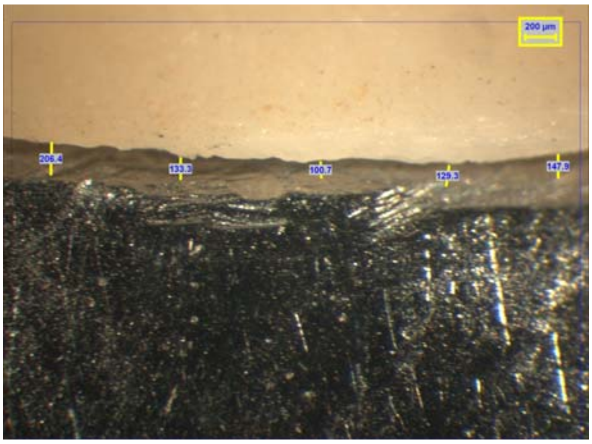


Fig 22 :- Stereomicroscopic image depicting marginal gap in Procera Allceram crown

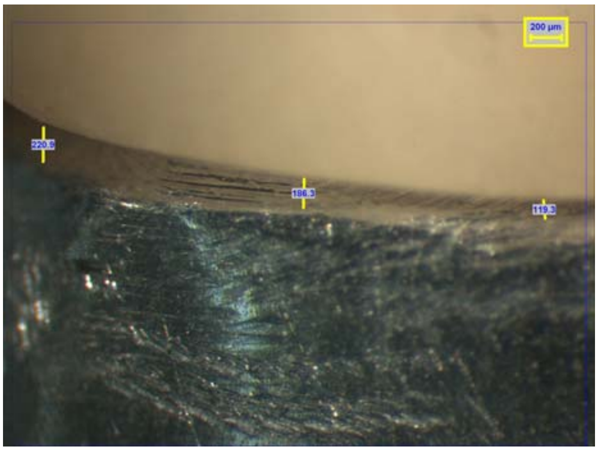
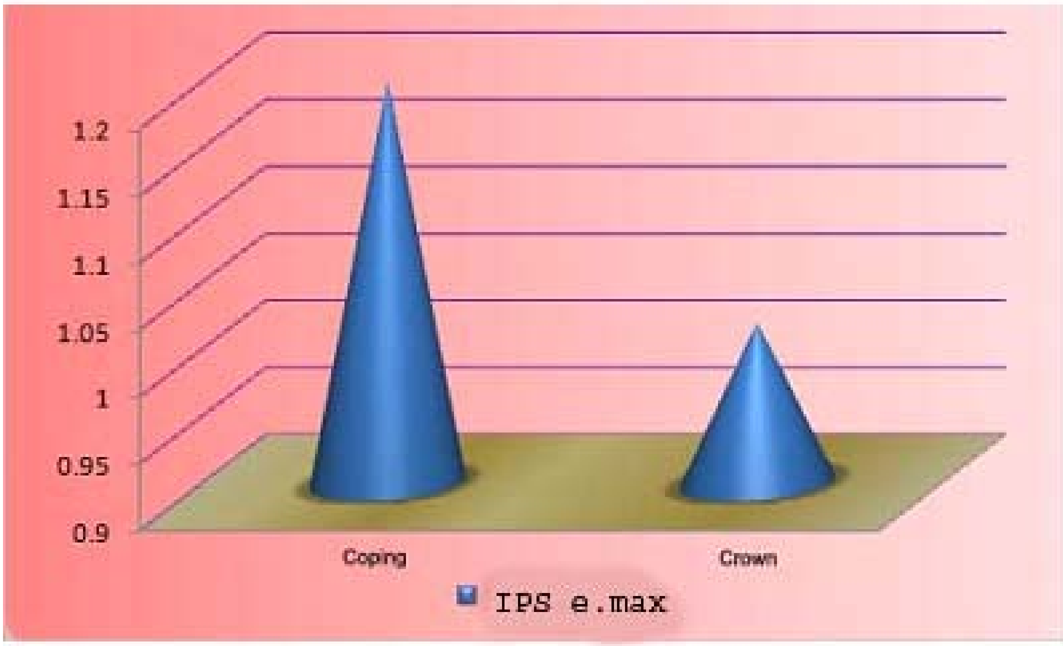
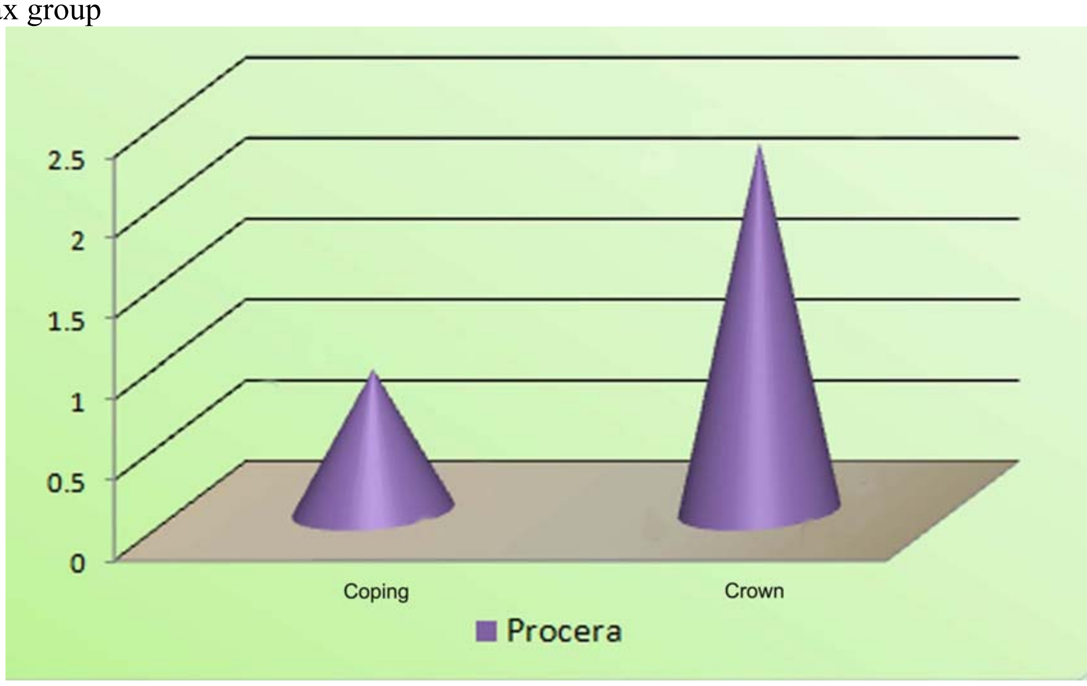


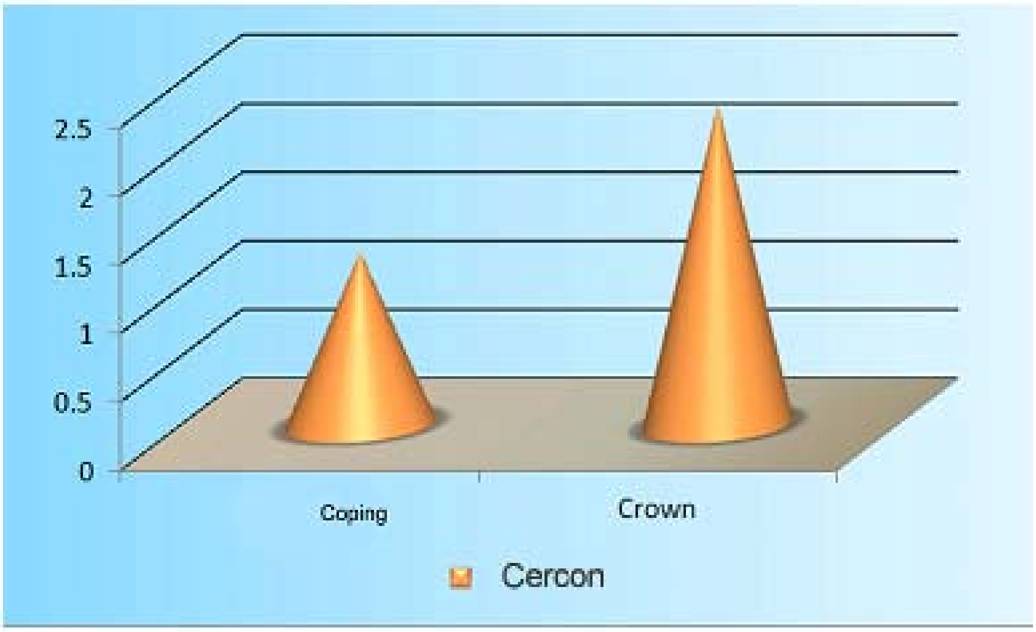
Fig 23:- Stereomicroscopic image depicting marginal gap in Cercon crown



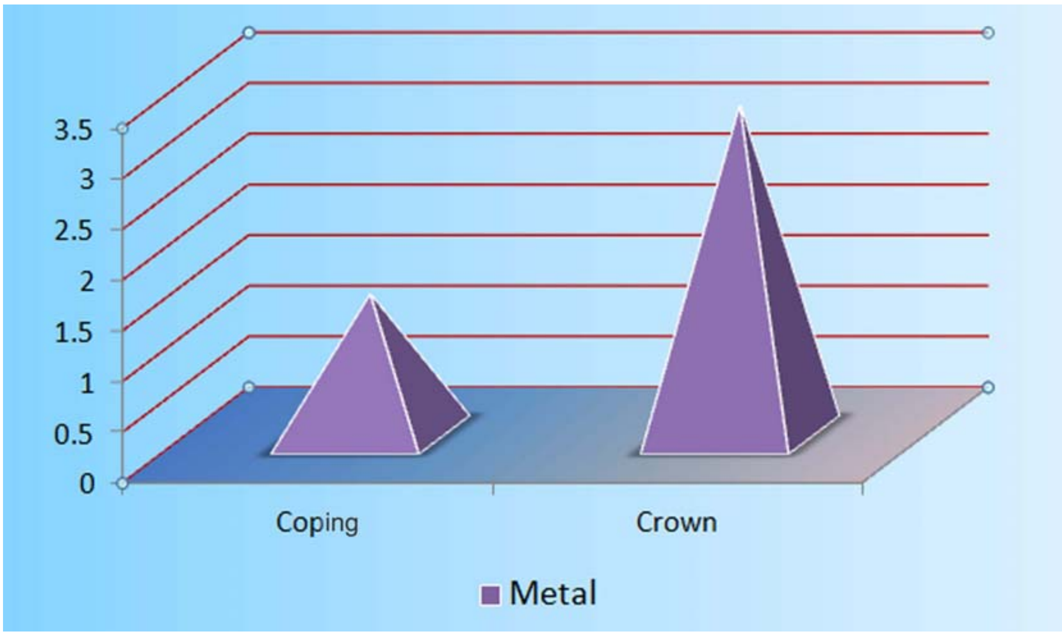
Graph 1 :- Graph depicting the mean fracture resistance values of copings and crowns of IPS-e.max group



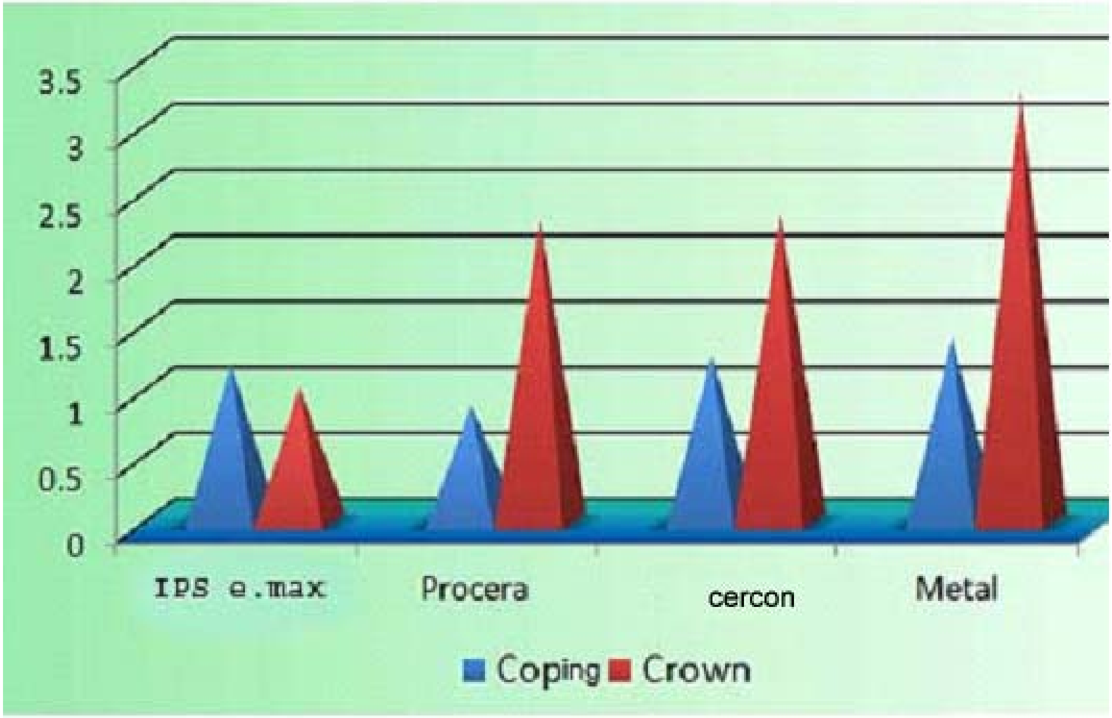
Graph 2:- Graph depicting the mean fracture resistance values of copings and crowns of Procera Allceram



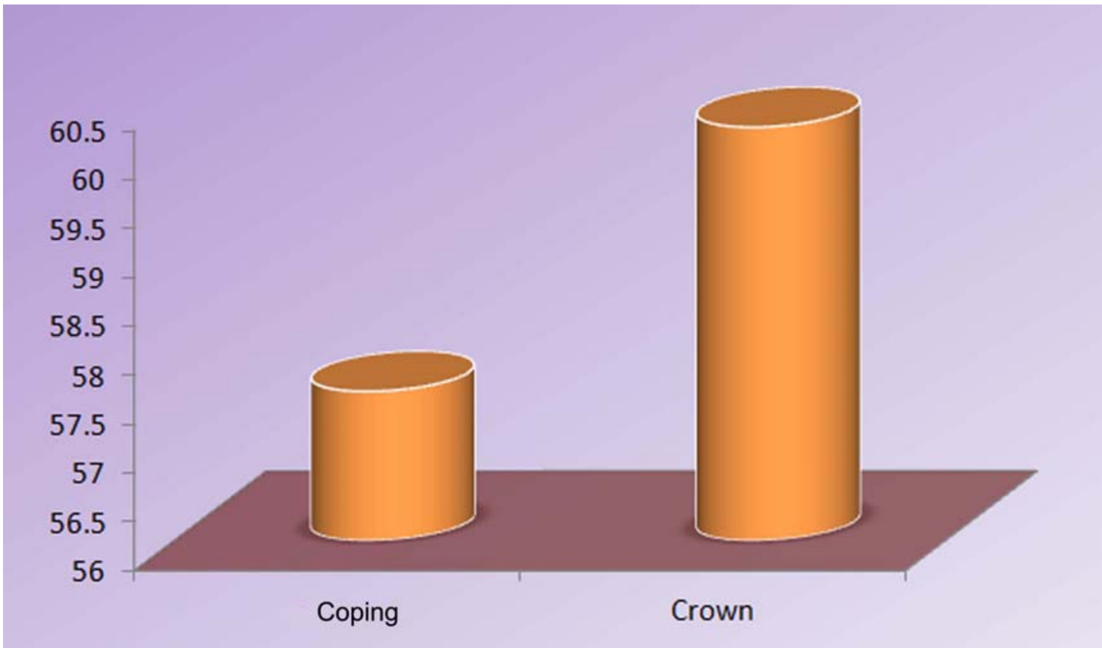
Graph 3 :- Graph depicting the mean fracture resistance values of copings and crowns of Cercon



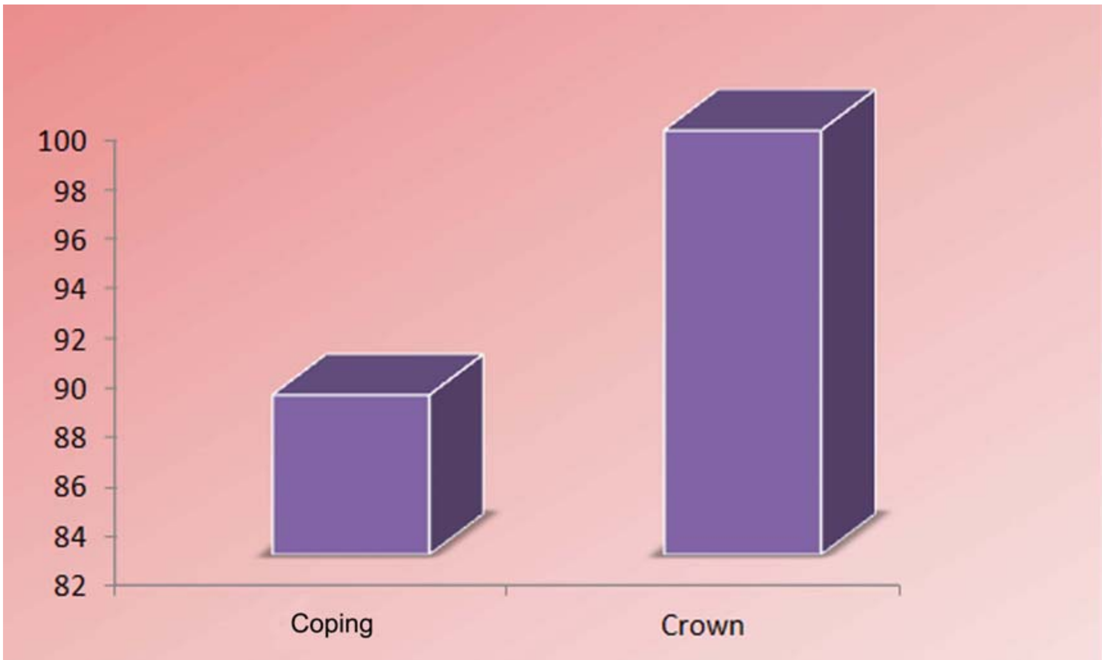
Graph 4 :- Graph depicting the mean fracture resistance values of copings and crowns of metal Wirobond C.



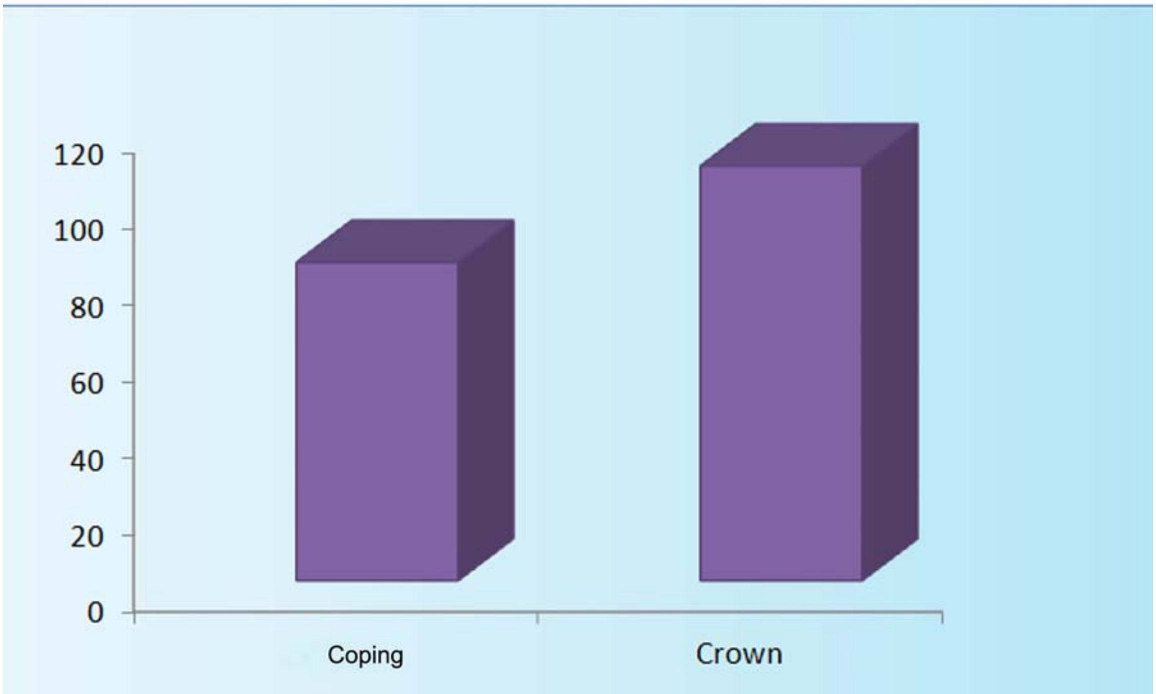
Graph 5 :- Graph depicting comparison of fracture resistance between groups (between materials) and within groups (coping and crown of each material)



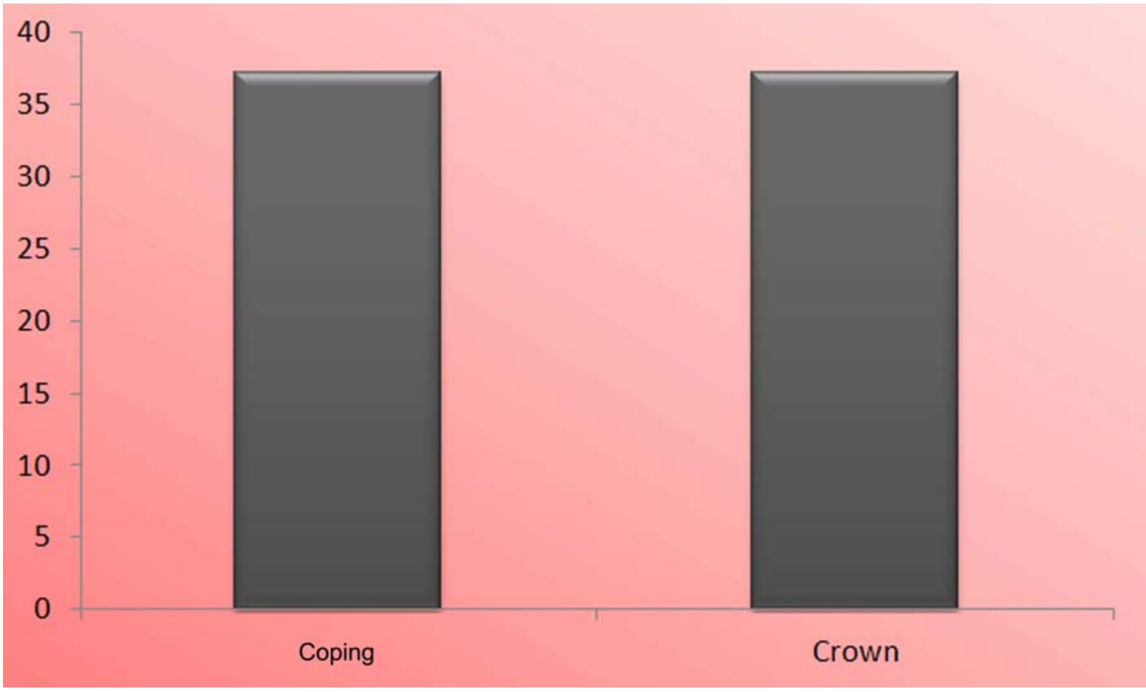
Graph 6 :- Graph depicting the mean marginal discrepancy values of copings and crowns of IPS-e.max group



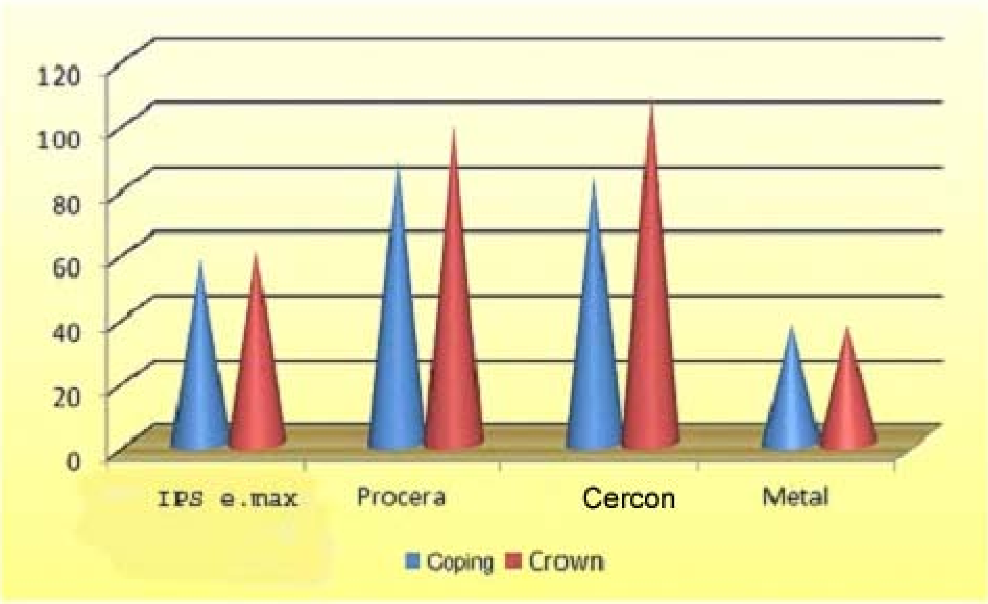
Graph 7 :- Graph depicting the mean marginal discrepancy values of copings and crowns of Procera Allceram group.



Graph 8 :- Graph depicting the mean marginal discrepancy values of copings and crowns of Cercon group.



Graph 9 :- Graph depicting the mean marginal discrepancy values of copings and crowns of metal Wirobond C.



Graph 10:- Graph depicting comparison of marginal discrepancy between groups (between materials) and within groups (coping and crown of each material)

Discussion

In the search for the ultimate esthetic restorative material, many new all-ceramic systems have been introduced to the market. For many years development of dental ceramics has centered on creating materials with the same optical properties of natural teeth and the all- porcelain restoration closely matched the translucency and value of natural dentition. While the need for extremely esthetic and natural restorations has become predominant in recent years, a reasonably predictable long-term clinical life span is also paramount. One of the deficiencies of early all-ceramic crowns such as the feldspathic porcelain jacket crown was its lack of such predictability. Many of the newer systems have been marketed heavily on the basis that these crowns are stronger or are reinforced with a core material that will prevent clinical fracture.

Ceramics fall into three main composition categories, that is predominantly glassy ceramic, particle filled glass ceramic and polycrystalline ceramic [39]. Highly esthetic dental ceramics have high glass content, and higher strength substructure ceramics are generally crystalline. Substructure ceramics have crystalline content ranging from approximately 55 % crystalline to fully polycrystalline. Predominantly glass ceramics are based on alumino silicate glass. Modifiers are added to control thermal expansion or / contraction behavior. In particle filled glass ceramics filler particles are added to the base composition to contrast color, opacity and opalescence. The fillers are usually crystalline or high melting glasses. They also enhance micromechanical bonding by dissolution during etching. Particles can be added mechanically during manufacturing as powder or be precipitated within the starting glass by special nucleation and growth heating treatments (termed glass ceramics).

Polycrystalline ceramics contain no glass; all of the atoms are packed into regular crystalline arrays through which it is more difficult to drive a crack than the irregular network found in glasses. Aluminia and zirconia are the only two polycrystalline ceramics suitable for use in dentistry as framework materials able to withstand large stresses. Computer aided manufacturing has made possible the application of polycrystalline ceramics practical for well fitting restorations.

Ceramics are brittle materials, because of the atomic bonds that do not allow the atomic planes to slide apart when subjected to load. Thus, ceramics cannot withstand deformation of >0.1% without fracturing [3]. Furthermore, the pre-existing flaws act as starting points for crack formation whenever ceramic constructions are loaded above a certain level [25]. Potiket et al [40] compared the in vitro fracture strength of natural teeth restored with Procera, Procera AllZirkon zirconia and a metal ceramic crown with a coping thickness of 0.6mm and found no significant difference. Hence All-ceramic crowns may be considered as an alternative for metal ceramic crowns in highly esthetic areas. The mean masticatory forces during mastication and swallowing in human beings have been reported to be approximately 40 N [11,31], whereas mean maximum posterior masticatory forces vary from 200 N to 540N [15,24]. But the fracture resistance values of various all-ceramic systems reported in literature is in the range of 400 Mpa[29] for IPS Empress II, 687 Mpa [18] for Procera and 620Mpa [32] for In-ceram zirconia. Hence they can also be used successfully for posterior restorations.

Metal free restorations have a strong ceramic core onto which layering ceramic is applied to achieve a natural appearance. High-strength ceramics for the cores of crowns and fixed partial dentures have been introduced and tested, both in vitro and in vivo [17, 36]. There are various factors affecting the failure loads of all-ceramic restorations including test methods, distribution of flaws, marginal gap [19] and veneering porcelain thickness [54]. In vitro studies do not account for the influence of prosthesis shape and dissimilar component material properties on the stress distribution. Hence it is preferable to test all components materials in a multilayered specimen to reproduce the flaw properties resulting from interfaces between the veneer materials, core materials, luting agent layer and dentin.

Long term clinical success of any restoration in the oral cavity is significantly influenced by marginal deviation. Lack of fit in an all-ceramic crown is detrimental to both tooth and supporting periodontal tissues. Poor marginal adaptation can result in increased plaque retention culminating in periodontal disease [4, 2], leakage around the margins resulting in pulpal inflammation [45] and dissolution of luting agent [9]. It has been proved that the misfit of a crown can affect the fracture strength [19] and thereby reduce the longevity of the crown. Marginal fit of the crown may be affected by preparation angle, finish lines [41], die spacer thickness, expansion of die stone, polymerization shrinkage of impression material, curvature of finish line [55], application of veneering porcelain, manufacturing technique [56], cementation process [33] and the seating force of the crown.

Although there are multiple studies analyzing the fracture resistance of all ceramic copings or veneered crowns separately, there are very few reports in literature dealing with fracture resistance of all-ceramic veneered crowns and copings in the same research project. Hence the present study is an attempt to compare the fracture resistance of copings and veneered crowns individually of the same all ceramic material. A standard metal coping and crown served as the control. Another variable that is being studied is the variability in marginal adaptation of the crown before and after veneering.

Three most commonly used posterior all-ceramic crown systems were compared for fracture resistance and marginal adaptation in the present study against a metal crown. The all-ceramic systems tested include IPS e.max (Ivoclar Vivadent), Procera All-ceram (Nobel Biocare, Sweden) and Cercon (Dentsply Degudent, Germany). A Cobalt chromium metal coping and crown (Wirobond C) of same dimensions, served as the standard.

The IPS e.max (Ivoclar Vivadent) lithium disilicate is composed of quartz, lithium dioxide, phosphor oxide, alumina, potassium oxide, and other components. These powders are combined to produce a glass melt which is poured into a separable steel mould to form blocks or ingots. The glass ingots or blocks are then processed using the lost-wax hot pressing techniques (IPS e.max Press) or state-of-the art CAD/CAM milling procedures (IPS e.max CAD). The microstructure of the pressable lithium disilicate (i.e., Li2Si2O5) material consists of approximately 70% volume of needle-like lithium disilicate crystals that are crystallized in a glassy matrix These crystals measure approximately 3 μm to 6 μm in length. A veneer porcelain consisting of fluorapatite crystals in an aluminosilicate glass may be layered on the core to create the final morphology and shade of the restoration. Fluorapitite is a fluoride-containing calcium phosphate, $Ca_5 (PO_4)_3F$. The fluorapitite crystals contribute to the veneering porcelain's optical properties and coefficient of thermal correction, so it matches the lithium-disilicate pressable or machinable material. Both the veneering and lithium-disilicate materials are etchable due to the glassy phase.

Procera Allceram (Nobel Biocare, Gotenberg, Sweden) is a polycrystalline ceramic from which a well fitting prosthesis is made by computer aided manufacturing. The ceramic core is milled and sintered in Sweden at the 'hub' laboratory using a digital prescription transmitted, by modem, from a 'spoke' laboratory in the UK. The coping is then returned to the 'spoke' laboratory for conventional build-up with specially developed dental porcelains (AllCeram Porcelain, Ducera).Once the tooth is prepared; an impression is made and poured in high strength dental stone. In the ‘spoke’ lab scanning of the die is done on a rotating platform with a digital scanner. The scanning probe incorporating a sapphire stylus approaches the die at a 45^0 angle and a light pressure of 20gm is used to ensure close contact during the scanning process. An average preparation requires 50,000 readings for accurate digitization and takes a time of 30 sec. The coping is designed on the computer taking into consideration the thickness of the coping needed, finish line and space required for the luting agent and this information is fed to the ‘hub’ lab in Sweden. The milling machine here has a milling tool of exactly the same dimensions and angle of approach as that of the sapphire stylus in the 'spoke' laboratory. The milling machine creates a duplicate of the preparation (enlarged by 20%) in the 'hub' laboratory onto which aluminum oxide is densely packed [26]. The aluminum oxide is machined to the proportions requested in the digital prescription and sintered to full density. Since the polycrystalline ceramics are opaque, they are veneered with glassy ceramics to achieve pleasing esthetics. Luting procedure can be carried out with zinc phosphate cement, glass ionomer cement or chemically cured resin cement such as Panavia 21 (Kuraray Co Ltd, Japan). As the fit surface of the aluminum oxide (Al_2O_3) coping is microscopically rough there is little to be gained by acid etching; surface treatment of the fit surface is therefore usually restricted to sandblasting and the application of a silane-coupling agent. It is suggested that Panavia 21 is the cement of choice [26]. This is supplied with a priming agent and the use of this coupled with a total etch procedure is recommended. Glass-ionomer cement has been advocated for use when moisture control is not optimal.

The Cercon all-ceramic is a polycrystalline ceramic introduced in 2002 by Dentsply Ceramco. The Cercon Zirconia system (Dentsply DeguDent, Germany) is an yttria partially stabilized zirconia (Y-TZP) ceramic. Y-TZP in the Cercon system is a fully-dense polycrystalline material consisting of very small grains with size ranging from 200 to 300 nm [51]. During fabrication, conventional waxing techniques is undertaken for designing the zirconia infrastructure followed by scanning of the pattern, enlarging the digitized framework, and milling out of the pattern from a prefabricated homogeneous porous blank of zirconia using Cercon-smart® ceramics system. The zirconia pattern is then sintered to full density for 2 hours at 1350°C to achieve the final infrastructure [46]. All compensation for the shrinkage factor of the Cercon core material during sintering is programmed into the Cercon system to ensure that a precisely designed coping or framework is produced for an ideal fit. Because of the inherent opacity and high value of all original zirconia blocks, corresponding porcelain overlay materials were developed and introduced to improve the cosmetic look of the resulting restorations. In 2004, Dentsply Ceramco introduced Cercon Ceram S followed by Ceramco PFZ that offered improved esthetics by increasing the vitality of the final restoration through the use of nanotechnology. In 2005, Cercon Ceram Kiss was introduced through Denstply DeguDent to provide a high-end cosmetic look while keeping the technique simple and straightforward for consistent results.

An important factor in the design of a dental prosthesis is strength, a mechanical property of a material that ensures that the prosthesis serves its intended functions effectively, safely and for a reasonable period of time. Strength is the stress necessary to cause either fracture (ultimate tensile strength) or a specified amount of plastic deformation [37] the strength is dependent upon several factors including the a) strain rate, b) shape of the test specimen, c) surface finish and d) environment in which a material is tested. The greatest disadvantage of all-ceramic restorations is most probably brittleness. This property is responsible for the fracture behavior of this category of materials. The limited capacity to undergo plastic deformation results in fracture at the first sign of overloading [30]. Fracture toughness or critical stress intensity is the mechanical property that describes the resistance of brittle material to the catastrophic propagation of flaws under an applied stress. It is inversely proportional to the square root of flaw depth into the surface [37].

Fracture test on ceramic specimens fabricated in the shape of anatomic configuration of teeth can be a useful tool for identification of their behavior [49]. The test includes loading the anatomic specimens up to failure point. Performance capacity of a new restorative material for a range of indications can be decided upon by comparing the results obtained from these types of in vitro studies with the values of well defined and accepted materials in the same experiment. Failure loads obtained are usually very high (about 1000 N) compared with the range of loads reported in the mouth (about 100 to 600 N). This means that stress state at failure and failure mechanism during in vitro experiments might be different from clinical conditions [27]. Hertezian contact instead of indentation contact and cyclic loading in a medium similar to oral environment have been suggested to provide a more similar simulation to the actual conditions of restorations performance. The results should be validated by well-designed clinical trials [27].

Loading of a ceramic restoration by a round intender has been frequently used to simulate cyclic occlusal contact [47,42,48].This study evaluated the fracture resistance of 3 different all-ceramic crown systems bonded to heat cure acrylic resin dies. The all-ceramic systems taken into consideration were the IPS e.max (Ivoclar Vivadent), Procera Allceram (Nobel Biocare) and Cercon (Dentsply), which were the most commonly, employed systems for fixed partial denture treatment. The fracture resistance values of these ceramic systems were compared against metal specimens which served as the control. Six test specimens were fabricated from each system, of which three were copings and three were complete veneered crowns. The fracture indentation tests were conducted for both copings and crowns to find out the influence of veneering on fracture resistance. A stainless steel ball bearing (5.25 mm in diameter) was centered on the occlusal surface of each specimen. Each specimen was occlusally loaded along the long axis to fracture in a universal testing machine (Model 3345; Instron Corp, Canton, Mass) at a crosshead speed of 1 mm/min and the maximum load was recorded from the load-displacement trace.

Several studies used steel or resin dies for the fracture testing of crowns [15, 13]. The advantages include standardized preparation and the identical physical quality of materials used. However, prepared teeth made of steel or resins do not reproduce the actual force distribution that occurs on crowns cemented on natural teeth [58]. If a crown is supported by a die made of high modulus of elasticity, the fracture strength will be dramatically increased compared with that of crowns supported by low modulus of elasticity [12]. This increases the probability that the load will result in indention damage at the loading site rather than reflect a fracture mode as seen in clinical failures [50]. Dentin has a lower elastic modulus than steel. Therefore, the greater deformation of the teeth, the higher the shear stress will be at the inner crown surface. As a result of deflection of dentine there will be a radial expansion at the cervical part of the dentin core as a result of wedging. The present study has made use of heat cure acrylic resin dies which are having a modulus of elasticity similar to that of dentin (14.7 GPa) [16].

The preparation design of the abutments used in this study included a 6-degree taper, which was shown to reveal no statistically significant difference in fracture resistance [16]. In vivo, a 90-degree shoulder with a rounded internal line angle is recommended for all-ceramic crowns [3].

The fracture loads obtained with the copings and crowns of this test group has shown a pattern that is not seen in usual clinical laboratory testing. The all-ceramic coping of Procera Allceram(0.88KN) has a fracture resistance value that is significantly less than that of IPS e.max (1.2KN) and Cercon (1.26KN). The IPS e.max coping has a value that is almost similar to that of Cercon copings (1.26 KN). The fracture resistance of IPS e.max may be higher than Procera All Ceram due to its glassy structure which allows for some amount of plastic deformation. As a result IPS e.max sustains larger load before ultimate fracture. Whereas Procera All Ceram can sustain less plastic deformation as a result of its polycrystalline structure. This explains its inability to sustain loads as high as that of IPS e.max. The higher fracture resistance value of Cercon crown may be due to transformation toughening of zirconia when subjected to compression. The strength values of all-ceramic copings of Cercon and IPS e.max were not statistically different from that of metal copings, but Procera Allceram coping had a significantly low strength when compared to the control metal. The metal coping did not undergo fracture, but only plastic deformation.

When the fracture resistance values of all-ceramic crowns were compared, it was observed that Cercon crown (2.34 KN) has the highest value followed by Procera (2.29 KN) and IPS e.max (1.02KN). The metal crown (3.26 KN) had the highest strength compared to all-ceramic crowns. The metal crowns were able to withstand high loads without fracture. But there was a flattening of the occlusal surface indicating permanent deformation. These results were in agreement with the studies conducted by Pallis et al [43] in which fracture resistance of three all-ceramic systems, that is, IPS Empress II, Procera Allceram and Inceram Zirconia were compared using a steel ball intender on individual anatomic model made of resin die. Procera Allceram had strength higher than IPS Empress and lower than zirconia [52].

When the fracture patterns of crowns were examined it was found that the IPS e-max exhibited a crushing of the veneering ceramic with partial fracture of the coping. On the other hand Cercon crowns exhibited a delamination of the veneering ceramic with exposure of core veneer interface. There was little or no fracture of the ceramic core. Aboushelib [52] studied the fracture mechanisms of IPS Empress and Cercon crowns and witnessed a similar phenomenon. Sundh and Sjogren [38] observed similar failure patterns for IPS Empress Crowns where most of the crowns failed by splitting and most zirconium veneered crowns failed by delamination. Clinically failed ceramic crowns demonstrate features that are consistent with cracks that originate at the cementation surface, and produces a much smaller number of fragments (typically two) compared with those in the laboratory, where crushing damage results in many fragments. The IPS e.max specimens in this study produced multiple fragments. The Procera All-ceram cores tended to remain intact when fracture occurred. This observation is supported by the in vitro test conducted by Webber et al [34], in which the compressive load at fracture of Procera All-ceram cores at varying thicknesses of veneering ceramic were compared and similar results were obtained. This may have been due to greater to a weaker bond of the All Ceram veneer porcelain to the core.

When fracture resistance values of copings and crowns of each system were compared it was found that IPS e.max coping and crown had similar strength values. It was interesting to note that for Procera All Ceram and Cercon crowns the fracture resistance values were significantly high when compared to the copings. The higher fracture resistance of Procera All Ceram and Cercon crowns when compared to copings can be explained on the basis of the fact that ceramics are stronger in compression than in tension. Hence, more the thickness more will be the strength. Since only direct loading of the test specimens has been carried out, there is little or no tensile or shear stresses acting. But clinically usually fracture or chipping of the veneering ceramic with the core intact is usually observed as a result of lateral forces. In a study conducted by Harrington et al [35] comparing the varying thicknesses of occlusal veneer on fracture resistance of Procera All ceram crowns similar results were obtained. The mean load at fracture for Procera core with no occlusal veneer porcelain was 419 N, whereas Procera core with 0.4-mm veneer porcelain was 702 N and Procera core with 0.9mm thick veneer was 1142 N. These results contrast with those of Zeng et al [23] who found that un-veneered alumina core material is stronger than the combined core-veneer porcelain structure. It was hypothesized that this is due to the fact that the veneer porcelain is weaker under tension and causes failure to occur at a much lower level of stress. An in vitro study by Hopkins [8] investigated the effect of adding various thicknesses of veneer porcelain to a core and found that the addition of even a thin layer of veneer porcelain to a core reduces its shell strength.

When evaluating the clinical success and quality of a restoration, marginal discrepancy is an essential criterion. The ideal cement thickness for a fixed restoration is 25 – 40 μm [1]. Christensen [1] reported the clinically detectable range for sub-gingival margins to be 34-119 μm and 2-51 μm for supra-gingival margins. The clinically acceptable limit of marginal gap for any indirect restoration is in the range of 100-120 μm [6,20]. Poor marginal adaptation can result in cement dissolution, micro leakage, increased plaque retention, and secondary decay. Absolute marginal discrepancy was defined as an angular combination of the horizontal and vertical error and would reflect the total misfit at that point. According to Holmes et al [7], there are many different locations between a tooth and a restoration where the measurements can be made, but marginal discrepancy (or accuracy), which would always be the largest measurement of error at the margin, is measured as the distance of the restoration to tooth structure right at the margins.

There are several techniques for assessing the marginal discrepancy of an indirect restoration such as direct viewing, sectioning, probing replicas [56] and explorative and visual examinations [7]. Laser videography is a reliable technique for assessing marginal discrepancy [22]. The stereomicroscope can be used as a supplement method for assessing castings on dies [60]. They may provide a higher degree of marginal gap detection prior to examination of these castings intraorally. This instrument is easy to use and is not considered costly. The present investigation employed a quantitative assessment of primary marginal fit of Procera All ceramic, Cercon and IPS e.max crowns by means of stereomicroscopy with 200× magnification, using eight measurement points (three buccal, three lingual and one each proximally) per sample and determined the fit before and after veneering the core with layering ceramic. The metal coping and crown served as the standard.

When the marginal adaptation of IPS e.max, Procera All Ceram and Cercon all ceramic copings were studied using stereomicroscopy and the values compared it was found that there was a significant difference between each group (Fig 18-23). The least amount of marginal gap was exhibited by IPS e.max copings (57.53 µm), followed by Cercon copings (83.35 µm). Procera All Ceram had the highest value (88.47 µm) compared to the other two systems. The metal coping presented with the least marginal discrepancy compared to the all ceramic systems.

The present study has made use of uniform 1mm wide modified shoulder preparation for all the systems compared. In vivo a 90^0 shoulder with a rounded internal line angle or moderate chamfer is recommended for all ceramic crowns [53,57]. Carefully smoothed tooth preparation margins are mandatory because the probe tip (sapphire ball) of a Procera scanner unit has a diameter of 2.5mm and is unable to locate irregularities and grooves with radii smaller than 1.25mm in the reading process. The scanner tip is rotated and probed around the dies vertical axis [44]. Contemporary chair side or laboratory- based CAD/CAM systems have additional factors that may affect the accuracy of the fit, including software limitations in designing restorations, and hardware limitations of the camera, scanning equipment, and milling machines. Clinicians' and dental technicians' experience and expertise is also key with chair side and laboratory- based CAD/CAM systems. Manufacturing technique [56] also influences the marginal fit of the crown. Both

Procera and Cercon technology creates an enlarged framework out of a pre sintered block. After milling it is removed from the die and sintered to correct size. The shrinkage produces an internal and marginal discrepancy between restoration and abutment. Hence the result obtained with copings can be justified and can be concluded that heat pressed IPS e.max ceramic copings have better marginal adaptation than polycrystalline milled copings.

Similar observations as that of copings were found when CAD/CAM processed Procera All Ceram and Cercon crowns were compared with heat pressed IPS e.max crowns. In the present study however, marginal gaps were shown to be significantly different after the porcelain veneering on their copings. This difference may be explained by the fact that during the porcelain veneering procedure, particles of porcelains melt and gather to fill up voids and the resulting contraction of the porcelain mass causes a compressive force on the coping [10].This result is in accordance with the study conducted by Hyun-soon et al [59]. The deformation of the coping under the stress of contracting porcelain is spread around the whole circumference of the margin. Sulaiman et al [49] and Beschnidt and Strub [28] reported no significant differences on the marginal gaps between copings of all-ceramic crowns and veneered all-ceramic crowns and concluded that veneering porcelain application has no effect on the fit of all ceramic crowns.

When the copings and crowns of all ceramic systems were compared, there was found to be a significant increase in marginal gap of crowns with respect to their copings. Cercon crown registered the maximum increase followed by Procera and IPS e.max. However the marginal misfit of metal crown was significantly low and remained the same regardless of coping or crown.

One of the major limitation of the study was that the ceramic specimens were loaded only in vertical direction which does not mimic the forces acting in the oral cavity, where they are subjected to lateral and horizontal forces. Since ceramics are stronger in compression the values obtained for failure in the present study were much above the average forces encountered in the mouth. This study does not provide any information about the long-term properties of the materials when exposed to the fatiguing stresses of mastication, and it did not attempt to reproduce the temperature changes to which restorations are exposed in the oral environment. Micro leakage and diffusion are potential sources of fluid for internal ceramic surfaces to initiate fracture growth. But this was not replicated in this laboratory study. However, the test specimens were made in a shape and size similar to clinical restorations and were supported by dies that also attempted to reproduce the modulus of elasticity of dentin.

The fracture resistance values of the all-ceramic systems tested, IPS e.max, Procera All Ceram and Cercon, were high enough to withstand maximum masticatory loads. Also the results obtained with both the copings and crowns of all-ceramic systems for marginal fit were within the limits of clinical acceptability and hence these all-ceramic systems can be successfully employed for both anterior and posterior restorations. The ability of the metal crown and coping to withstand stresses were higher than that of any all-ceramic system compared. Also metal crown exhibited excellent marginal adaptation than metal free systems.

Summary & Conclusion

Copings and crowns of three different metal free ceramic system and metal crown samples were used in the present study to evaluate the fracture resistance.

The following inferences can be drawn from the study.

1. The values of fracture resistance obtained for the copings and crowns of IPS, E-max were almost similar. There was no significant difference in fracture resistance between them.

2. While fracture resistance of crowns of Procera All Ceram, Cercon and metal Wirobond C were significantly higher than their corresponding coping.

3. When tested fracture resistance of Procera All Ceram coping was significantly low in comparison to copings of IPS e.max, Cercon and metal Wirobond C.

4. Fracture resistance of IPS e.max, Cercon and metal Wirobond C coping were statistically similar.

5. Fracture resistance of IPS e.max crown was significantly low in comparison to all other groups.

6. There was a statistically significant increase in marginal discrepancy of three all-ceramic system crowns when compared to their corresponding copings.

7. There was no difference in marginal gap between metal coping and crown.

8. Maximum marginal gap was exhibited by Procera All Ceram coping when compared to copings of other three groups.

9. When marginal gaps of crowns were compared it was found that Cercon crown presented with maximum marginal gap.

Hence it can be concluded that the fracture resistance of machinable ceramic crowns such as Procera All Ceram and Cercon increase with the addition of veneering porcelain. But pressable ceramic such as IPS e.max did not show marked increase in strength when veneered with porcelain. Also the strength of its coping is significantly lower than other two machinable systems. Hence in posterior areas where aesthetics is not critical thickness of the pressable coping can be increased for additional strength, especially when cost is considered.

All the three all-ceramic systems registered an increase in marginal discrepancy of crowns compared to copings, with the maximum for Cercon followed by Procera All Ceram and IPS e.max. Hence marginal fit of pressable ceramic outshines the machinable systems although strength properties are inferior.

The control metal group appeared to be the best in terms of strength and marginal adaptation.

However the fracture resistance of all the three all-ceramic systems were high enough to withstand maximum masticatory loads and hence could be successfully used for posterior restorations. Also marginal gap of all three systems compared were below the clinically acceptable value of 120µm. Hence longevity with these restorations can also be expected.

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